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The University of the State of New York

New York State Museum

John M. Clarke, Director

PLEISTOCENE MARINE SUBMERGENCE OF THE HUDSON, CHAMPLAIN AND ST LAWRENCE VALLEYS

BY

HERMAN L. FAIRCHILD

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

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The University of the State of New York
Science Department, November 8, 1918

Dr John H. Finley
President of the University

SIR:

I beg to communicate herewith and to recommend for publication, as a Bulletin of the State Museum, a manuscript report entitled *The Pleistocene Marine Submergence of the Hudson, Champlain and St Lawrence Valleys* which has been prepared, at my request, by Prof. Herman L. Fairchild.

Very respectfully
JOHN M. CLARKE
Director

THE UNIVERSITY OF THE STATE OF NEW YORK
OFFICE OF THE PRESIDENT

Approved for publication this 12th day of November 1918

John H. Finley
President of the University

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JOHN M. CLARK, *Director*

PLEISTOCENE MARINE SUBMERGENCE OF THE HUDSON, CHAMPLAIN AND ST LAWRENCE VALLEYS

BY HERMAN L. FAIRCHILD

INTRODUCTION

This is the closing paper of a series on the glacial waters in New York State published as bulletins of the New York State Museum. These bulletins, with other papers, described the successive stages of the glacial lakes and drainage down to the time of Lake Iroquois, the latest of the glacial lakes. (See nos. 154–64 of the bibliographic list.)

The glacial history had been carried eastward through the Mohawk valley to the Hudson valley, and the writer thought that his task would be completed when the Lake Iroquois history ended with the extinction of the lake in the "Champlain sea." In the prosecution of this study the Iroquois shore was traced northeastward on the northwest flank of the Adirondack highland to the second and final outlet of the lake, at the pass south of Covey hill on the international boundary, with altitude far over 1000 feet.

It was expected that the waters inferior to Iroquois in the Ontario-St Lawrence basin would correlate with Woodworth's water levels in the Champlain valley (81, 82). But a complication appeared when shore-line features were found in the St Lawrence valley at altitudes beneath the Iroquois plane but much above the supposed marine plane, and even above Woodworth's "Lake Vermont." These beaches were first noted by Prof. G. H. Chadwick, in the Canton district. The first tentative explanation of these

intermediate shore lines attributed them to glacial waters controlled by the ice front on the Champlain side of the Covey Hill salient. This necessitated an examination of the Champlain valley features, and eventually led to a comparison of the high-level water planes throughout the entire Champlain-Hudson valley. With the help of later topographic surveys and new maps it was found that the supposed glacial waters in the Hudson valley (Lake Albany) and in the Champlain section (Lake Vermont) were in fact only northward extension of sea-level waters. It appeared that the amount of land depression at the close of glaciation was greater than had been supposed.

Abundant phenomena of the summit level of the marine flooding were mapped on both sides of the great valley, rising steadily from zero south of New York City to 740 feet at Covey pass. Many of these features were noted by Woodworth. The series of heavy cobble bars at Covey Hill post office, which curves about the Covey salient and back into New York south of Chateaugay village, were found to be inferior by over 200 feet to the summit marine plane. The summit plane of the sea-level waters passed far above the points of supposed glacial lake control, and it became evident that no glacial waters were ever held the whole width of the Hudson-Champlain valley. The negative reasons will be stated later. Several years of further study in New York, Vermont and the Connecticut valley confirms the above philosophy. The facts are partially on record in former papers (nos. 26, 27, 55, 69, 89–93).

Not until recently have the topographic maps been available for clearly depicting the shore-line features about the Covey promontory and in the St Lawrence valley, which is the explanation of the late date of this report.[1]

The glacial features in the Hudson-Champlain valley have been described by Professor Woodworth in Bulletin 84 (no. 82 of the appended bibliography) and Bulletin 83, on the Mooers quadrangle (81). In these writings Professor Woodworth gave emphasis to the glacial features; the stages of the waning glacier and the dwindling ice tongues, the positions and form of the ice margins, the ice contacts, the moraines, the outwash and glacial terraces.

The intent of the present writing is to draw attention to the proofs of marine submergence and to describe the more striking features, and to aid in the study of the diastrophic problem connected with the latest glaciation.

[1] Grateful acknowledgment is made to the Hon. James R. Macfarlane, of Pittsburgh, Pa., for providing transportation in the Malone–Potsdam district.

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ABSENCE OF LAKES IN THE HUDSON-CHAMPLAIN VALLEY

Following the latest ice sheet no waters were held in the valley above sea level, and the earlier geologists were right in attributing the deltas and shore features to an incursion of the sea. But in later years the assumption of even higher elevation of the land instead of lower at the time of the ice removal, and the postulation of lakes in the valley instead of sea-level water, makes some present discussion of the subject necessary.

It is evident that no waters could be hemmed in by glacier ice on the south; hence there could be no glacier lakes. And the term "glacial" applied to the Albany and Vermont waters is a misnomer. The only possible high-level or lake waters would be "morainal" or "drift barrier"; or lakes with land barrier. In other words, any nonmarine waters in the Hudson-Champlain valley would have required either morainal blockade or uplift of land on the south.

Long ago Upham assumed land uplift of the continental border in order to hold up the Champlain high waters (5, page 486; 6, page 508). We now find that the summit water plane in the valley, clearly marked by abundance of shore phenomena (see plate 10), does not drop to sea level until far south of Staten island, and the gratuitous land barrier would have to lie far out to sea; and would have to extend around the New England coast so as to block off Long Island sound. This conception of a land barrier has no basis in any evidence or argument submitted, and may be dismissed. Land uplift in the Glens Falls district sufficient to block the earlier and higher Champlain waters is disproved later in this writing.

Morainal dams might be postulated for the narrow places in the Hudson valley. The most suggestive location for a drift barrier is at the Narrows, the crossing by the terminal moraine. But it will be recognized that the escaping waters would effect a passage through the narrow dam of morainal drift. The Hudson waters were deep and long lived, as proved by the extensive and thick clays and the broad deltas, and no drift barrier could stand up for any length of time against heavy outflow. In this connection it must be realized that the outflow carried not only the land drainage of that time but the large volume of water from the melting glacier; and that after the ice front had receded as far north as Albany all the drainage now carried by the St Lawrence river, augmented by the ablation of a thousand miles of the ice front, passed out through the Hudson valley. These facts apply also to any other location of

possible drift barrier, like the narrow section of the Highland, below West Point. And no belt of drift, marking any strong recessional moraine, has been recognized in the valley north of the terminal moraine. It may be noted that a blockade at the Narrows would be ineffective with the Harlem valley and Long Island sound open.

For the Champlain valley a possible land barrier is the col or divide between Fort Edward and Whitehall. But it has been shown (93, page 10) that the divide is not a river channel, or at least has not carried any stream flow in Postwisconsin time. Moreover the conspicuous terraces built in standing water lie, continuous, on both sides of the valley up to 300 feet over the col. Indeed, it is important to note that at any point where any kind of dam can be proposed, in either the Hudson or the Champlain section of the great valley, the evidence of long-standing water will be found immediately below (south of) the dam site at an altitude quite as high as above (north of) the station.

An idea has been held that some of the shore features, especially for the valleys of New England, were the product of ice-border lakes; the waters being held in embayments of the valley walls by the lobations of the ice margin. In the Hudson-Champlain valley such lateral pondings would be possible at only a few localities, where deep embayments or tributary valleys were limited on the south by bold salients. A steady water level of some duration would require a land outlet, and such should be dicoverable. If the escape of the water was alongside the ice margin, as must nearly always have been the case, the impounded waters would be inconstant in level and ephemeral, and the shore features would be weak and indefinite. Even if recognizable deltas or other inscriptions were left by the marginal waters, those of the separate lakes would have no consistent relationship in altitude. The only localities in the great valley where shore phenomena are found that might suggest marginal waters are at West Point, Crown Point, Port Henry and at Port Kent and Keeseville. But even granting the efficiency of marginal lakes in a few embayments, this does not explain the fact of strong, practically continuous and consistent shore features the whole length of the valley. Marginal glacial waters are probably a negligible factor in the Hudson-Champlain valley, and for all the New England valleys that declined away from the ice front directly toward the open sea.

A fair consideration of the factors involved in the valley history, and of the features seen in the field, will rule lake waters out

of consideration. No rational explanation of the high-level water plane in the Hudson-Champlain valley is found except confluence with the sea. In other words, the waters were estuarine; as long ago recognized by Mather, Merrill, Ries, Davis and Darton. No facts or serious arguments have ever been presented to meet the evidence of marine submergence in the lower Hudson presented long ago by these eminent geologists. After describing high-level terraces in New Jersey, Staten island, Long Island and the lower Hudson, which could have no other than oceanic relation (82, pages 90–114) Woodworth postulated lake waters in the upper Hudson and for the higher Champlain beaches. Veatch, Fuller and Crosby have asserted that the land stood at or above its present level when the ice sheet abandoned Long Island, but they do not mention the abundant evidence of deep waters in the lower Hudson district given in the writings of the men named above, including Salisbury for later writings. It is unquestioned that we have marine fossils up to 300 or 400 feet altitude in the Champlain valley, and water-laid terraces up to 80 feet in the New York region, facing the open sea. Hence the doubtful element would seem to be only the status of the Hudson valley and the higher Champlain features. Instead of further negative discussion let us take up the positive side.

EVIDENCE OF OCEAN-LEVEL WATERS

1 Character of the Valley Deposits

The widespread and deep clays of the Connecticut, Hudson and Champlain valleys, and in the Winooski and Lamoille valleys tributary to the Champlain, are clear proof of deep or at least quiet waters. In the Champlain region the clays are very extensive and carry marine fossils, but are not genetically different from those of the Connecticut or Hudson.

In the Hudson valley, one of the greatest brick-making districts in America, the clays rest on till or glaciated rock. Their horizontality and undisturbed character show that they have not been overridden by any ice sheet, and are of Postwisconsin age. The infrequent crumpling observed is common in silt and clay beds, as an effect of slumping. Their large content of lime and occasional occurrence of large glacial boulders proves that the waters were laving the receding ice front.

The capping of sand and gravel over the clay beds is a necessary effect of the shallowing waters, due to the land uplift; the land

streams extending their flow and spreading coarse detritus over earlier deep-water deposits. The heavier clay areas are the deltas of the larger tributary rivers, where the detritus of land drainage was added to the glacial contribution.

It is probable that in some sections of the Hudson valley the clay strata extended entirely across the channel, and that the present beds are only remnants of the original deposits. Certainly the clays were laid down in water of depth sufficient to give very quiet conditions, but now they lie far above the water. In the section of the valley at Newburgh, Kingston and Catskill the homogeneous brick clays extend up to over 100 feet above the water, and in places have a thickness of 140 feet. The map of isobases (plate 9) shows a total uplift at Kingston of about 200 feet, which affords the requisite depth for accumulation of the thick deposit.

In the Connecticut valley the massive clays extend far north. At Wells River, Vermont, the top of a pit by a brick factory is 535 feet above tide, and the uplift of the locality has been about 650 feet. At Waterbury, on the Winooski river, at least 70 feet of clay is exposed, reaching up to about 510 feet, and lying on about the same isobase as Wells River. Any number of localities might be cited to prove from thick clay deposits the fact of deep water, and showing the correspondence of the present altitude with the amount of land uplift since glacial time.

Details concerning the Hudson clays will be found in Ries's articles (33–36), and with regard to depth and distribution in the paper of C. C. Jones (40).

2 Summit Shore Phenomena

Evidences of high-level standing water throughout the great valley, and at heights now far above sea level, are obtrusive to even the casual observer. Some careful study reveals that the summit plane of the raised shore line is practically continuous from Staten island to Canada. The only long breaks in the line of summit features are along the Palisades and in the narrow mountain sections of the valley, in the Highlands and the Whitehall district, where the steep rock walls gave no lodgment for the meager amount of either glacial or stream drift. On Manhattan island and about New York bay the building operations and "improvement" have largely destroyed or obscured the water inscriptions of the geologic record.

Woodworth records terraces in New Jersey with altitude of 40 feet (82, page 88); on Long Island, up to 80 feet (page 91, and 51,

page 645); and northward up the Hudson at rising levels. Salisbury after years of detailed study of the New Jersey Pleistocene concluded that the state had been submerged since the ice removal to a depth of 100 feet on the north boundary (41, pages 196–213, 508–13). It will be seen in the diagram (plate 10) that these elevations agree with the projected plane of the upraised shore line. As this plane does not drop to sea level until far south of New York there seems no way of excluding the tide, and we must believe that these shore features are oceanic.

The line of shore phenomena, rising steadily northward, is clearly marked all the way to Canada, except for the breaks above noted, and on both sides of the great valley. The altitudes on the two sides of the valley coincide perfectly, on the isobases (see maps). The shore features are found in excellent form in Vermont, with altitude agreement with the New York shore; and have been described in paper no. 92.

The important fact to note is, that this shore line is a unit; it was produced by a single body of water. A second important fact is, that the water stood at sea level, was confluent with the ocean, following the receding ice front.

The broad, conspicuous sand plains and the stronger beaches are commonly inferior to the summit or initial level, especially in the Champlain valley. The determination of the summit plane, which is commonly weak, may require special study.

At the earliest level the waters lay 650 feet deep over what is now the north end of Lake Champlain; and were 300 feet over the Fort Edward divide.

It is interesting, as a bit of economic geography, to note that many villages and cities are built on the delta sand plains of this water level. Examples are West Haverstraw, North Haverstraw, Peekskill, West Point, Newburgh, Beacon, Wappinger Falls, Poughkeepsie, Hyde Park, Kingston, Rhinebeck, Saugerties, Kinderhook, Niverville, Ballston Spa, Greenwich and Elizabethtown. In Vermont, several villages are on plains of inferior or later levels. Bristol is situated on a summit delta plain built by the New Haven river where it emerged from the Green mountains and poured into the sea-level waters (92, page 22).

3 Differential Uplift of the Marine Shore Line

Plates 9 and 10

The deformation of the shore line throughout the Hudson-Champlain and St Lawrence-Ontario valleys proves that the val-

leys were far below sea level when the latest ice sheet withdrew. The Iroquois shore line adds positive confirmation.

The deformation or tilting is due to northward differential uplift. It would only introduce complexity and unreason to assume that the New York end of the shore line had subsided from some higher position. And it must be admitted that the shore line, as a consistent unit, representing a single water body, was originally horizontal.

The accompanying maps and the diagram (plate 10) give the main facts showing the uplift of the territory. It will be very difficult to determine the point of no uplift, as the southern border of the tilted area must grade imperceptibly into the unaffected area. It is also recognized that minor positive and negative movements, and perhaps some unknown factors, have possibly confused the record. Where the old shore has an altitude less than 20 or 30 feet the wave inscriptions are weak and equivocal.

Some details regarding the character of the shore line and the plotting of the line in plate 10 belong in a later chapter (page 23).

4 Evidence of Uplift from Lake Iroquois

Plates 4–7

The Iroquois shore, taken by itself, clearly proves the large uplift at Covey hill. In conjunction with the shore lines of the higher and earlier glacial lakes it is positive that the deformation is a northward uplift, in direction N 20° E.

The Iroquois beach is now well known throughout the entire basin, from Hamilton, Ontario, to the place of its extinction. It is the closing level of a single water body. The beach rises from 362 feet at Hamilton to 1030 feet at the Covey outlet. This gives a northward differential uplift at Covey outlet of 668 feet. The north boundary of the State was therefore as much as 668 feet lower than it is today at the time when Lake Iroquois was extinguished. And it was also as much lower than the 668 feet by whatever amount Hamilton has risen since the death of Iroquois. A glance at plate 9 shows that the total uplift at Hamilton in Glacial time is 195 feet, which has been determined by the differential uplift of the glacial lake beaches earlier than Iroquois. The tabulation of data, plate 12, makes the Post-Iroquois uplift at Hamilton 72 feet. That is to say, that of the 195 feet rise at Hamilton only 72 feet is needed to add to the 668 feet at Covey in order to make the 740 feet uplift shown by the marine shore.

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5 Evidence from the Connecticut Valley and Long Island

Plate 3

The Connecticut valley, like the Hudson, is filled with clay and sand plains, deltas, terraces and occasionally beaches due to deep standing water. The valley held an estuary contemporaneous with the Hudson-Champlain estuary. The facts for the Connecticut valley have been concisely given in a former publication (69).

The isobases in plate 9 were originally drawn to connect points of equal altitude on the marine shores of the Connecticut and the Hudson valleys; and they are found to be in accord with all knowledge to date.

An examination of Long Island shows that it was also submerged to the extent indicated by the isobases; and the facts are on record in a recent paper (55). The proofs of Long Island submergence, especially at the eastern end of the island, are so abundant and evident that it seems strange they should have been so long overlooked.

It will be found that these isobasal lines of plate 9, with some greater curvature, will mark the amount of the Postglacial submergence and subsequent uplift of New England and the Maritime provinces.

6 Postglacial Submergence of New England and Canada

It is well known that New England and eastern Canada have been elevated since glacial time. The occurrence of abundant marine fossils in extensive areas and far above present sea level is indisputable proof of submergence. But the extent of the submergence has probably not been appreciated, and certainly has not been accurately determined.

The Canadian geologists have recorded many evidences of standing waters and many localities of marine fossils at high altitudes in the St Lawrence and Ottawa valleys, and eastward, to which the geologists of the United States have not given sufficient attention. The occurrence of marine fossils far over present sea level and other evidences of deep glacial and postglacial submergence caused the Canadian geologists to place some overemphasis on the work of floating ice and icebergs in explanation of the glacial phenomena. But it must be admitted that in the fact of deep marine waters over eastern Canada the Canadian students had very good basis for their ice-flotation theory.

The recognition of the work of the Labradorian ice sheet over

most of the glaciated territory as that of land ice has resulted in the neglect, especially by the geologists of the United States, of the evidences of deep marine submergence in Canada and New England. With the emphasis on land glaciation we have discounted or ignored the former observations of the "diluvialists" and "icebergists," and have minimized the amount of land depression during the removal of the ice sheet, and have neglected its study.

The writings of Robert Bell, J. W. Dawson, R. W. Ells, Robert Chalmers and A. P. Low contain much reliable data concerning the occurrence of marine organisms at high altitudes and of broad sand plains and extensive deep clays, all pointing to widespread and deep oceanic waters. A few of the writings of the authors named above, and of A. P. Coleman for the Ontario district, are listed in the bibliography. A good resumé of the studies up to 1897 is given by Ells (143). The Canadians found evidence of submergence to 1000 feet or over as far west as Montreal and the Ottawa valley. Sir William Dawson's claim of shore features at a height of 750 feet on Mount Royal is probably true, for it now appears that the marine waters passed over the summit. The marine plane is 800 feet at the south end of Lake Memphramagog.

7 Testimony of Former Students

All the earlier geologists in referring to the features of the Hudson valley assumed their estuarine character. As early as 1843 Mather listed the larger deltas north of Newburgh and Fishkill, and in his summary said: "It is considered evident that a vast inland sea once occupied what may be called the basin of the St Lawrence and Hudson valleys since the period of the drift deposits." (28, page 157).

In 1891 F. J. H. Merrill published two papers in description of the Hudson deposits and recognized their estuarine character, and the delta origin of the Albany-Schenectady plain. His figure for the submergence at New York City was 80 feet, which is correct for the north end of Manhattan island. In this paper he noted the terraces on Staten island, and correlated them with the broad sand plains of the south side of Long Island and with the plains in the Hudson valley. He seems to have been the first geologist to appreciate the relationship of these detached features. And he showed his insight and appreciation of the problem by giving the first explanation, and a true one, for the absence of beaches. This point will be considered later.

In 1891 and 1892 Heinrich Ries published descriptions of the massive clays of the Hudson valley (33, 34), from Croton Point to Albany, and in later publications (35, 36) gave detailed description which proved their estuarine origin.

N. H. Darton, in 1894, published descriptions of the Pleistocene deposits of the counties of Albany (38) and Ulster (39). He also regarded the deposits as the "products of a submergence at the close of the Glacial epoch," and drew a map of the "Champlain submergence" of the Albany district (38, page 359).

An admirable description of the delta of the Catskill in the Hudson estuary was published by W. M. Davis in 1892 (37). He clearly recognized that the Champlain submergence involved the Hudson valley. His value for the summit of the Catskill delta, about 275 feet, is precisely correct, as shown by the profile, plate 10.

In his Glacial Geology of New Jersey, R. D. Salisbury describes the features due to Postglacial submergence, and says that the water plane has about 100 feet altitude at the north border of the state. This is in accordance with the plotted profile.

Some later writers on Long Island stratigraphy and glacial beds have assumed or asserted an uplifted attitude of the lower Hudson district, but have passed over the earlier writings and entirely ignored the clear and positive evidence of submergence.

For the Connecticut valley the detailed studies of B. K. Emerson show conclusively that the high sand plains and the extensive clay fields were the products of standing water, which he called "Connecticut lakes," and could not be the results of a swollen river (66, 67). His altitudes for the water plane on the north and south lines of Massachusetts are values used in the map of isobases, plate 9.

Students of the Champlain section of the great valley have made too much distinction between the lower deposits which carry salt-water fossils and the upper plains and terraces without fossils. There is probably also a psychologic factor involved. The invoking of "glacial waters" may have been due in part to a tendency to utilize the new thought in Pleistocene geology, the existence and effect of ice-dammed waters. The recognition of glacial lakes came during the seventies of the past century,[1] and has been a most useful conception. But it was always incumbent on an author who postulated glacial waters to find the control, or locate the outlet and correlate the levels and beaches with their outlets. There

[1] Proc. Amer. Assn. Adv. Sci., 47: 285–287; Amer. Geol., 22: 183–86. 1898.

has been too much reference of static water features of unknown relationship to "glacial" without proving the fact. The writer can not be charged with any prejudice against glacial lakes; but he has named no lake without knowing its control.

ABSENCE OF MARINE LIFE IN THE HUDSON VALLEY

No well-attested marine fossils have been found in the Hudson valley, or in the higher water-laid deposits of the Champlain valley. Partly for this reason the appeal has been made to glacial waters.

The tides are felt in the Hudson " river" to Albany, but brackish water reaches only to about Poughkeepsie, and salt water organisms pass up the Hudson only to the Highlands. The problem relating to the Pleistocene waters becomes simply the exclusion of salt water.

When the receding ice front was slowly giving place to the deep estuarine water in the Hudson valley these were loaded with silt, for the land drainage was gathering in the freshly laid mantle of drift and the melting glacier was contributing its load of rock flour. The thick clay beds resting on the till or glaciated rock are sufficient evidence. The waters were cold and muddy, and unfavorable to nearly all forms of marine life.

Another deterrent factor was the volume of fresh water. The ablation of the glacier probably supplied, even in the lower Hudson, sufficient fresh water to exclude the salt-water fauna. And when the ice front receded to Albany the flood from the Ontario basin swept into the Hudson, and for long ages subsequent all the drainage now represented by the St Lawrence, plus the water from the melting of the ice sheet for a thousand miles on the west, were forced south through the narrow passes at Whitehall, West Point and the Palisades. And during this stage the wave uplift of the glaciated territory had probably lifted the lower Hudson valley to nearly its present height. Such uplifted condition is indicated in the maps, plates 1 and 2.

When the ice front reached Covey hill the outdrainage of the Laurentian basin was merely shifted from the Mohawk pass to the Covey pass, and the cold, fresh waters still passed south. When the ice front recession let Lake Iroquois fall and blend into the sea-level waters, so that the latter occupied the Ontario basin (see plates 2, 3, 5), the ultimate outlet was the same. And this southward flow through the Hudson of all the glacial waters, and the land drainage, from Duluth to Maine, persisted until the waning of

the ice margin on Maine and New Brunswick opened a strait to the St Lawrence gulf. Then, but not before, salt waters entered the lower St Lawrence valley, and slowly worked up into the Champlain valley.

However, by the time salt water reached the Champlain valley a decided change in the physiography had occurred. During the many thousands of years in the history sketched above land uplift had been in progress in the areas relieved of the burden of the ice cap, and the earlier shore lines of the Hudson-Champlain had undoubtedly been raised much above the waters. How much elevation had occurred before salt-water life entered the Champlain waters we can not now determine. A lifting of 300 feet at Fort Edward, of the 450 feet total rise, would have entirely broken the connection between the Champlain and the Hudson waters. And long before the connection was broken the long stretch of the narrow strait with its receipt of land drainage from a large territory from both Vermont and New York would have discouraged marine life from making the southward journey.

It would appear from the known history and the probable physical conditions that marine fossils should not be found in the Hudson valley or in the higher Champlain deposits.

ABSENCE OF BEACHES IN THE STATEN ISLAND REGION

No continuous beaches (bars, cliffs and terraces) would be expected in the narrow stretches of the Hudson valley. But the absence of distinct, positive beaches on the New Jersey coast, Staten Island and Long Island has been a cause of perplexity even to those who accept postglacial submergence. The necessity for beaches on a submerged land has been tacitly assumed by most writers. It is believed that this assumption is wrong.

Merrill realized this difficulty, and was the first writer to suggest an explanation (30, pages 105–9). In a recent paper the writer quoted liberally from Merrill's argument (55, pages 299, 301), but for the present purpose it may be sufficient to quote the conclusion of his analysis of the mechanics of beach erosion:

. . . for the present purpose which is simply to point out the fact that a land surface in process of subsidence or emergence may be subjected to wave action without being incised with distinct shore lines, and also that *wave action may produce an inclined plane as well as a terrace or base level.*

It is therefore evident that submergence would not leave a deeply cut shore line as its record unless the rates of land movement were so adjusted as to

permit of it. In fact no very distinctly cut shore lines are to be found on the drift about New York even at an altitude corresponding to that of the Hudson estuary deposits. Apart from the still-water deposits the 80-foot postglacial depression about New York can only be traced by change of surface slope and material at this level. Even these two varieties of evidence are not always coexistent.

Beach phenomena have scarcely been recognized on territory of New England which was almost certainly submerged during the removal of the ice sheet. Professor Shaler explained the lack of beaches on Martha's Vineyard and Nantucket by the too rapid lifting of the shores.[1]

To the above sound and quite sufficient argument something may be added. On the open sea shores of Long Island and Staten Island there was an inhibiting factor besides the rising of the land, namely, the tidal fluctuations of level. A very little change in the water level may effect large difference in the force and direction of shore currents and effectively change the plane of bar construction or of beach erosion.

However, there is an erosion cliff on the face of Staten island and on the west end of Long Island as far as Lake Surprise, 6 miles beyond Jamaica. This has been recognized as a possible beach, and Fuller has given a clear description of it as "the great inland cliff of western Long Island" (54, page 54). He clearly proves the origin of the cliff as by marine erosion, but makes it earlier than the end of the Wisconsin epoch. But the altitude and slant of this and the Staten Island cliff agree with our map, plate 9.

The above discussion relates particularly to erosional shore features. Constructional features, bars and embankments are more common and under favorable conditions more readily produced by waves. It might properly be expected that bars and beach ridges would appear, especially on the broad sand plains of the south side of Long Island. The lack of such phenomena has been a strong point for these who assert nonsubmergence.

Students of ancient shore lines find gaps along beaches that are commonly strong. It requires considerable time for wave and shore currents, even at steady levels, to bridge unfavorable stretches. On shores as strong as those of the glacial Lake Warren and Lake Iroquois localities are found with only smooth, wave-washed slopes comparable to the low surfaces of Long Island and Staten Island. Following the removal of the sheet the land rose

[1] Geology of Martha's Vineyard. Seventh Annual Rep't, U. S. Geol. Survey, 1888, p. 321.

rapidly (or slowly, according to mental viewpoint) and the mechanical conditions produced by the constant shifting of the zone of wave attack were unfavorable for bar construction, especially in tidal waters, the same as for erosional work.

And there is another deterrent factor which has not been recognized in this study, of perhaps even more effect than the change of water level. Plates 3–5 show the location of beaches about the Covey Hill salient. The summit marine shore is very strong on the Champlain side of the highland, being represented in places by remarkable vertical series of strong cobble bars and gravel banks as far south as the parallel of Port Kent, the south edge of the Dannemora quadrangle, plate 8. On the lower slope of Covey hill at an elevation of 525 feet, 215 feet below the summit shore, is a splendid series of heavy cobble bars, which was formerly thought to represent the marine summit. The top of this inferior series of bars lies at Covey Hill post office, and curves westward about the hill at Stockwell, Maritana and Franklin Center, and enters New York north of Chateaugay. When we follow this shore line south from Covey hill we find a notable set of bars one mile south of the international boundary, and a good display at Sciota and also west of West Chazy. But as we pass farther south, on to the Dannemora quadrangle the shore features of the Franklin Center series practically disappear. On the north edge of the sheet, 2 miles northeast of West Plattsburg, this level of the lowering waters is only a rolling plain of sand, like many other broad stretches in the submerged Champlain region all devoid of beach phenomena. But the waters stood here just as long as they did at Covey Hill post office and Franklin Center, and the conditions of slope, exposure, open sea, etc., were just as favorable for bar-building. What is the explanation? Apparently the difference was due to the character of the material within the grasp of the waves. All the bars in the district are coarse gravel or cobble, never sand. Along the marine summit the glacial drainage built wide tracts of very coarse material, which the waves quickly piled into bars. When the gravel tracts were lifted above the waters and the waves found only sand they were unable in the time permitted to bank it at any particular level.

All the strong beaches of the sea-level waters of the Hudson, Champlain and St Lawrence valleys are coarse material, never sand. Even the steadier level of Lake Iroquois produced only cobble bars in the stretch of shorter lived waters between Water-

town and Covey pass. On extensive delta plains with superabundance of sand all beach features are wanting. Even where there was considerable coarse material an abundance of sand appears to have inhibited bar construction. It appears that wave work can much more quickly pile cobble into ridges, but that sand requires more time. The small sand bars that have been found were in sheltered localities with weak wave action.

The combined deterrent effect of shifting water level, tidal fluctuation, and dominance of sand or silt seems to be, in the light of facts from other districts, sufficient explanation of the absence of high-level beaches in the sandy areas along the sea coast.

EXPLANATION OF MAPS AND DIAGRAMS

PLATES 1–11

Plates 1 and 2. These maps are in completion of the series of maps showing the recession of the ice sheet over New York State, published in New York State Museum Bulletin 160, plates 9–17. Plate 1 shows the relation of the ice margin to the Iroquois and marine waters during the second, and closing, stage of the glacial Lake Iroquois, with the outflow at the pass on the international boundary, on the south side of Covey hill. Lake Iroquois is here at its greatest extension.

In the earlier maps the waters in the Hudson-Champlain valley were wrongly represented as glacial. This is now known to be an error. The low attitude of the land at the time of the ice removal permitted the oceanic waters to enter the great valley and persistently lave the receding ice front. At the time represented in these two maps the sea-level or estuarine waters had become contracted, diminished in depth and width, in consequence of the uplift of the land, which as a progressive wave had passed northward, subsequent to the ice removal. Plate 3 shows the full amount of the land submergence and the greatest extent of the sea-level waters.

In the Hudson valley it is probable that the land uplift never overtook the retreating ice front; but it is possible that some little uplift occurred in the Champlain district while the ice had the position indicated in plate 1. The effect on the shore line will be considered under plates 5, 10.

Plate 2 represents the ice margin as removed from Covey hill, thus allowing equality of level between the waters of the Champlain and St Lawrence valleys. Lingering points of the ice lobes are hypothetically depicted on the north edge of the map.

The difference in time between the stages shown in plates 1 and 2 is relatively small, and no attempt is made to show the slightly greater constriction of the valley waters in the Hudson during the second stage.

Plate 3. This map does not show the geography at any moment of time, but the greatest submergence and widest extent of the sea-level waters in all districts, as indicated by the summit shore features. The land uplift as a progressive wave, moving northward, produced constant reduction of the estuary on the south, while near the ice front the land was at, or near, its greatest depression and the waters at their maximum extent. This is illustrated in plates 1 and 2.

The amount of marine submergence and postglacial uplift is shown approximately by the lines of equal uplift, or isobases.

Plate 4. This map is intended to show the locations of the shore lines in the northern part of the State, east, north and west of the Adirondack highland.

In the Champlain valley only the sea-level waters, the marine inlet, existed, but in the St Lawrence valley the glacial Lake Iroquois preceded the ocean-level waters. The vertical interval between the Iroquois and the marine planes is 290 feet (see plate 11). The marine plane passes under Lake Ontario at the south edge of the area here shown, or approaching Oswego. The rise of the land, over 500 feet, at the head of the St Lawrence (plate 9) has lifted the surface of Lake Ontario to 246 feet above the sea, and buried the southwest shore of the sea-level waters (Gilbert gulf), where the land uplift was less.

Plate 5. We have in this map the shore phenomena plotted on the topographic sheets. The legend and notes make the map quite self-explanatory. Plate 6 joins the west edge of plate 5, and plate 8 joins the south edge.

In his map of the Mooers sheet Woodworth indicates many fragments of beaches which are not here shown (81, with map). However, the lower shore features do not involve any important element in the history, as such are to be expected, under favoring conditions, at all inferior levels. Weak bars occur irregularly at points where the several factors favoring their construction were present in sufficient degree.

The lower bars in this map belong mostly to the Franklin Center-Stockwell-Covey Hill post office shore line. This shore with its great series of strong cobble beaches represents a level 215 feet beneath the summit plane, and possibly records an episode of some-

what slower uplift of the district. But this shore series is practically limited to the area of this map. It is not found on the Dannemora quadrangle (plate 8), and is not recognized farther south.

The contouring of the Mooers sheet is not correct and no precise elevations are given; and the location of bars and of the interpolated shore line may need some correction.

The Mooers quadrangle includes the extensive bare-rock areas, due to the stripping of drift from the Potsdam sandstone by the copious glacial waters (see plate 5). The remarkable development of cobble bars indicated in the northwest and southeast parts of the Mooers sheet was due to the abundance of coarse material swept down by the glacial ice-border rivers to within reach of the standing waters. The cobble tracts are the deltas of the glacial streams. Long stretches of the summit shore have not been closely examined. More detailed description of the features of the map will be given in a later chapter.

Plate 6. This map, the Malone sheet, shows the westward extension of the shore lines, the map joining plate 5.

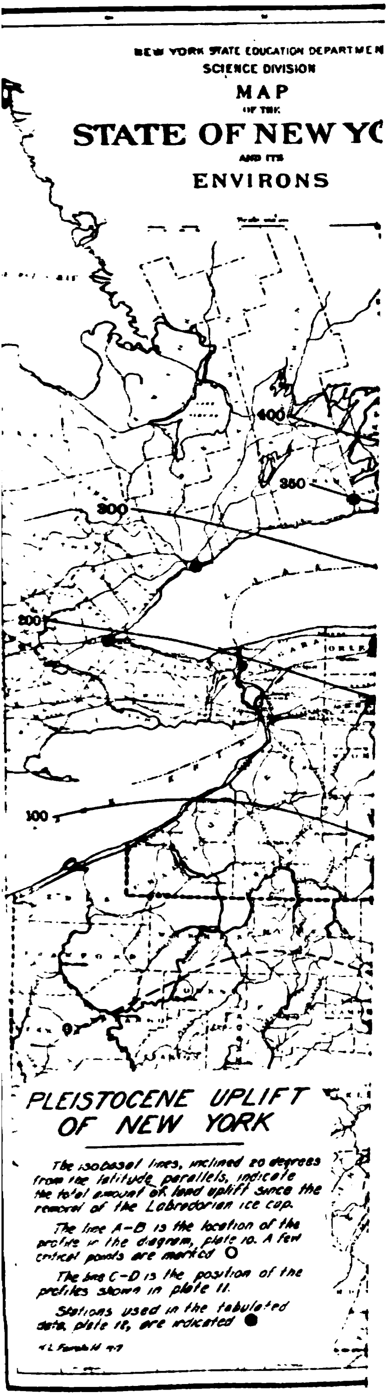
Below the marine plane the deltas are mapped only for the Salmon and Trout rivers, but sand and silt plains occupy most of the northern part of the area.

On the Moira quadrangle, lying west of the Malone, the shores merely cross the southeast corner, without significant features for the Iroquois and the marine summit, though a lower beach has strong development between Moira and Lawrenceville and west of the latter village. The quadrangle south of the Moira has not been mapped, but it carries heavy deltas and bars on the St Regis river at Dickinson Center and Nicholville. The next sheet available for our purpose is the Potsdam.

Plate 7. The Potsdam quadrangle, carrying the deltas of the west branch of the St Regis and the Raquette rivers, has good display of the shore features.

Interesting features occur on the Canton quadrangle, lying on the west of the Potsdam, but as Professor Chadwick plans to publish the Pleistocene geology of that area, it is not here included.

Plate 8. This map, the Dannemora quadrangle, joins the Mooers sheet (plate 5) on the south. As on the Mooers sheet, the highest reach of the sea-level waters is marked by the termination of the land and ice-border rivers, with their correlating deltas. West of Peru a few gravel bars lie above the theoretic marine plane, but series of heavy bars are beneath the summit level, which is the prevailing relation on all the shores of the marine inlet.


NEW YORK STATE EDUCATION DEPARTMEN
SCIENCE DIVISION
MAP
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PLEISTOCENE UPLIFT OF NEW YORK
The isobasal lines, inclined 20 degrees from the latitude parallels, indicate the total amount of land uplift since the removal of the Labradorian ice cap.
The line A–B is the location of the profile in the diagram, plate 10. A few critical points are marked
The line C–D is the position of the profiles shown in plate 11.
Stations used in the tabulated data, plate 12, are indicated

Plate 9. This map relates to the diastrophic problem, the deformation of the continental surface. The amount of uplift out of the sea is approximately shown by the isobases for all of the State and the neighboring territory. The map is to be used in connection with the tabulated data, plate 12.

In the Hudson-Champlain and Connecticut valleys the estuary, sea-level waters have left a record of the submergence in the shore features. The height of those features today is the measure of the postglacial uplift. The lines of equal uplift, isobases, connect points of equal rise in the two valleys; and the lines have been extended westward across the State. Across New York the isobases have nearly direct courses, 20 degrees north of west by south of east. It is recognized that the extended isobases must lie in circles or ovals about the domed area of uplift, and that both east and west they must be given decided curvature. On the east the curvature is determined by study of the land uplift in New England. Westward the curvature is hypothetic.

The lines of 300 and 400 feet are located in accordance with the determinations of Professor Emerson (66, 67). The zero isobase should, it is probable, be laid farther south, but as it is an uncertain and elusive element the line is drawn well within the limits of the map.

It will be seen that the rate of tilting, or gradient, of the shore line increases toward the north, as indicated by the spacing of the isobases. From present knowledge it appears that the steepest gradient lies over the Champlain district, and that the surface of the dome of uplift has a decreasing slope in Canada. The height of the estuary features in Lake Memphremagog district have located the 800 feet isobase.

Plate 10. This profile has been drawn to connect points of clear summit shore features. These stations are numbered on the chart, 10, 22, 24, 50, 54, 58, 78, 89, 138, 144. The fact that nearly all the topmost shore features, even in localities as far away as the Connecticut valley and the east shore by the Green mountains, coincide very closely with this profile is confirmation of its accuracy. And the vertical relation is greatly exaggerated, as the vertical scale is 528 times the horizontal.

Since the isobases are inclined 20 degrees from the latitude parallels and this profile is for a meridian, the proper location of the stations is by the intersection of their isobases, and the results are surprisingly harmonious. In only three localities are summit bars found at heights above this profile. These are at Crown Point,

111; Port Henry, 114; and 131, in the Ausable river embayn near Peru. As these are in decided embayments of the west of the valley it is possible that the high features are due to gl waters, or lakes lateral to the ice lobation in the valley. Howe the strength of the bars and their regular spacing does not fa the idea of ephemeral waters like the narrow pondings along the ice. It appears probable that the profile does not show the t height of the marine inlet waters in the Champlain lake distr The profile certainly does give the uplifted plane of the sea-le waters in the Champlain valley at the time those waters pas around into the St Lawrence valley. It therefore seems as there might have been some little rise of the land in the Champl region while the ice front lay about Covey hill, and that the super beaches indicate the amount of such lifting above the datum pla This has an important bearing on the relation of the land upl to the withdrawal of the ice cap.

It seems quite certain that through the Hudson valley, or about Glens Falls, number 89 of the profile, the wave uplift d not overtake the retreating ice front. By the time the ice c had waned so as to expose the Champlain valley the weight of t ice mass had so diminished that perhaps the northward-progressi wave of land rise did affect the border of the ice-covered territor This is also suggested by the Iroquois beaches in the St Lawren valley.

The history of the postglacial phenomena is possibly more con plex than here outlined, and there may be unrecognized factors i the problem.

The lower bars along the international boundary are mappe in plate 5.

Woodworth's line A-B in his plate 28 (no. 82 of the list o writings), is nearly coincident with this profile.

Plate 11. This diagram should be used in conjunction with the maps, plates 5-7, 9.

The shore features are plotted on the profiles according to their isobases. The vertical scale is 264 times the horizontal.

The lines for the uplifted Iroquois shore are drawn as straight lines from Covey outlet to beyond Adams, ignoring any slight curvature. Southwestward from Adams the line is given slight curvature so as to intersect the Iroquois beach at Ontario, Wayne county.

The upper of the two lines of Iroquois is regarded as the closing or extinction plane of the lake. If this be true then the lower line

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probably marks the low water following the opening of the second, Covey pass, outlet. If this is the correct interpretation then the water level fell, in the shift from the Rome to the Covey outlet, perhaps 40 or 50 or more feet. Then the rise of the land in the Covey Hill district while the Covey pass carried the outflow of Iroquois apparently raised the lake level about 22 feet at Richland and 15 feet at Farr's, near Watertown. The increasing vertical interval toward the southwest, and the character of the lower beaches, suggest the work of rising water.

This moderate rise of the land at Covey hill while the ice front lay at that point was not recognized in former writings (27), but it appears to be the only explanation of the shore features as plotted in the diagram; and the best explanation of the excessively elevated beaches in the Champlain district, described above.

The profile for the uplifted marine plane is also drawn as a straight line from Covey to Woodville, and beyond is given a curvature parallel with the upper line of Iroquois.

At Covey outlet the vertical interval between the closing Iroquois and the sea-level plane is 290 feet (1030–740). It is thought that no appreciable uplift occurred while the waters were cutting and melting their passage by the ice front on the steep north face of Covey hill, during the down-draining of Lake Iroquois into the Champlain waters at sea level. In horizontal distance on the northeast face of Covey hill the fall from 1030 down to 740 feet is only about one-half of a mile. Whatever rise of the district took place during this episode must be negligible in this study. With this view the vertical interval between the latest Iroquois and the earliest marine planes must everywhere be 290 feet. The summit marine features are fairly distinguished and fall into the profile line, plotted by isobase intersections. The interval of 290 feet marks the upper line of the Iroquois as the closing plane. And it should be noted that beyond Richland, or south of the Rome isobase, the Iroquois beach is a unit, a single heavy bar with steep front; and this correlates with the upper line of the diagram.

The unity of the western beaches suggests some close relation between the closing level of the lake and the former Rome level. It is possible that the lifting at Covey pass raised the closing level to an equality with the Rome level in the western end of the basin. The waters could not rise above the Rome outlet.

Some variation of the bars in height from the profile is explained by their distant location from the datum line (see plate 9) and the direction of maximum uplift. It will be seen that the direction

of the line of the profiles (C–D of plates 4 and 9) makes an angle of over 30 degrees with the direction of steepest uptilting, 20 degrees east of north. In consequence of this variance in direction the stations north of the line of the profile have an excess of altitude, while those south show a deficiency. Examples of the higher value are seen in all the stations on the marine shore profile between Chateaugay and Dexter; and on the Iroquois profile west of Ontario. The effect of southing is clearly seen at Rome, Woodard and Sodus.

The shore features which stand much above the profile, all the way from Lacona to Chateaugay, indicate some uplift of that region in excess of the uplift at the outlet, since the height of the outlet controlled the water level. In other words, the territory north of the isobase of Rome was lifted out of the Iroquois waters. The question is, When did this occur? The matter will be discussed in the next chapter.

DEFORMATION AND ALTITUDES IN THE ONTARIO BASIN

TABULATION OF DATA, PLATE 12

The uniform vertical interval of 290 feet between the Iroquois and marine planes in the St Lawrence-Ontario basin provides us with a master key to the amount of land uplift during two time divisions, the Iroquois or glacial time, and the Post-Iroquois or postglacial time. Wherever we can determine the height of either the closing Iroquois or the marine plane we can calculate the other one. The marine or sea-level altitude in the Ontario basin measures the amount of Post-Iroquois uplift. By subtracting this from the total uplift, as shown by the isobases (plate 9), we determine, for that point in space, the amount of uplift previous to the extinction of Iroquois, which for New York is glacial time. And the total uplift, the isobasal value, when subtracted from the present altitude of the point, gives us the height of that point before uplifting began.

The tabulation gives examples of the analysis; and comparison of the data in the table with the map of isobases reveals some interesting facts. It is found that Hamilton, Ontario, at the extreme west end of Lake Iroquois, received during glacial time more than half, about three-fifths, of its total uplift. Rome, at the southeastern extremity of the lake, and the outlet, suffered more than half its rise during glacial time. And these two

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localities were the first to be relieved of the burden of the ice sheet (164, plates 9–17). Other localities between Rome and Hamilton had proportionate movement. It will be seen that Rome was the point of largest rise in glacial time, and the station of lowest initial altitude. From Rome northward the glacial uplift was small, but the postglacial was large. Toward Canada nearly all the rise has taken place since the sea-level waters entered the St Lawrence valley.

The low initial height of Rome is in agreement with the facts of the early glacial drainage in central New York; for the escape long before Iroquois time was eastward through Syracuse to the Mohawk-Hudson; and the Syracuse channels are today, after uplifting and some filling, less than 400 feet above tide. In applying the mathematics of the table to any particular locality it must be understood that the figures apply to the precise point used for Iroquois or marine altitude. Taking Rome as example, the altitude, 460 feet, is the crest of beaches southwest of the city. The lowest part of the divide, the channel head or wasteweir of the latest outflow of Iroquois, the Iromohawk river, is about 430 feet. Hence the initial altitude of that point is 30 feet less than 110, or 80 feet. If we add 20 feet for depth of water we have a fall of 100 feet for the river flow between Rome and Schenectady, a distance of 92 miles by the railroad.

The initial height of localities can be approximately estimated by comparison with any near-by shore line (latest) of Iroquois, or a summit beach of Gilbert gulf.

The profile of the closing Iroquois, plate 11, shows that from Lacona to Chateaugay, or in the area north of the Rome isobase, there are shore features higher than the lake level. This implies that the land rose out of the water; in other words, the rise of the outlet, either at Rome or Covey, did not keep pace with the land uplift in the Watertown-Malone district. The greatest vertical spacing or splitting of the bars is at Farr's, 3 miles east of Watertown, where the highest beach is 62 feet above the profile. The table shows that Farr's rose only 69 feet during the whole of Iroquois time. But Rome rose 180 feet before and 170 feet after the extinction of Iroquois. It does not seem possible that Farr's could rise 62 feet over Rome in only 69 feet of total rise. The better explanation is that the northern uplift took place rapidly just after the outflow was shifted to Covey, as that outlet, and hence the water level, rose only a small amount before the extinction of the lake. Certainly the land uplift in the Watertown dis-

trict exceeded the rise of the water level by the 62 feet of vertical spacing. The relatively stationary attitude of the lake after the Covey outlet became effective gave the wave of land uplift the opportunity of rising out of water. It may be noted, as illustration and proof of the wave movement that during glacial (Iroquois) time Rome was lifted 111 feet more than Farr's, but that during Post-Iroquois (Postglacial for New York) time Farr's rose 211 feet more than Rome. In way of summary, it may be stated that south of Rome, which was on the fulcral line for nearly all the life of Iroquois, all the beach phenomena appear to an effect of rising water; that north of the fulcral line the splitting of beaches declines in amount both toward and beyond Watertown; that the tabulated figures for the Canadian stations show similar relation; and that the splitting of the bars is due to a local uplift of the ice-unloaded territory during the relatively short period that the lake outlet was at Covey pass.

The south shore of Lake Iroquois has the characters produced by a rising water level. Evidently the rise of the lake surface was produced by the excessive rise, or differential uplift, at the outlets, especially at Rome. The huge gravel bar at Hamilton is the most striking feature due to the rise of the lake. This has been described by Coleman (151, pages 351–52), who implied that the flooding by the rise of the lake level was toward 100 feet. Our tabulation shows that while Rome was lifted 180 feet, Hamilton was lifted only 123 feet, and the flooding at that point was 57 feet. It is an interesting fact that "unworn Mammoth remains" were found in the Hamilton bar at a depth of 83 feet (151, page 352).

By similar calculation the approximate amount of flooding is estimated for other stations. The figures are maximum, and probably slightly excessive, being as much above the fact as the uplift at Rome, after the outflow was shifted to Covey, exceeds the rise at Covey. As this difference is unknown, but probably small, the comparison of stations is made with Rome.

The beaches in Canada show relations similar to those in New York. The figures are chiefly Professor Coleman's. Toronto, on nearly the same isobase as East Gaines with about the same relation to the ice body, has similar figures, the glacial uplift being two-fifths of the total. But Quays, on the same isobase as Rome, but much longer under the weight of the glacier, received less than one-fourth of its rise in glacial time. The district north from Quays shows declining glacial uplift and increasing postglacial, similar to northern New York.

From the data at hand it appears that New York State was not raised as a rigid body but by a progressive wave movement. The south side of the Iroquois basin suffered about one-half of its total rise during Iroquois time. The northern part of the basin was lifted very little until after extinction of Iroquois. The New York City district did not rise at all until the ice was gone, for not until the ice front had withdrawn considerable distance was there any effective reduction in the weight of the ice cap. The question is, Did the wave uplift of the land ever overtake the receding margin of the waning glacier? In a former paper the writer expressed a negative opinion (27, page 250), but with further study and in the light of the accompanying charts it seems probable that some small rise occurred at Covey hill while the thin ice margin yet lingered against that northern salient.

DESCRIPTION OF THE SHORE FEATURES

Long Island

The amount of Postwisconsin submergence is shown in plate 3. The positive evidences of submergence are abundant and sufficient, the only ones lacking being bars of wave construction and marine fossils. The absence of bars on sand plains has been described in an earlier chapter; and absence of fossils on a shore of abundant drifting sand is probably to be expected.

This subject has been recently traversed in a published paper (55), to which the reader is referred for fuller discussion. For this present writing it will be sufficient to enumerate some of the characters which prove the burial in the open sea.

1 The island lies entirely within the area of postglacial depression.

2 Positive proof of the submergence of the near-by valleys of the Hudson and Connecticut.

3 The evident shore lines about the eastern moraines.

4 The admitted wave-eroded origin of the cliff extending from the west end of the island to 6 miles beyond Jamaica.

5 The very smooth, even surface of the lower parts of the area.

6 The materials of the plains and the occurrence of surficial loams over large tracts of the lower plains.

7 The subdued, wave-smoothed surfaces of the moraines beneath the theoretic plane, and the very rough, harsh, unsubdued surface of the same moraines above that plane.

8 The presence of innumerable kettles in the smooth eastern plains, showing the subjugation by standing waters of the ice-laid or moraine drift.

9 The admitted delta terraces or sand plains on the north side of the island, and on the north side of the latest moraine, at the theoretic altitude of the marine plane.

10 The occurrence of fine, evenly bedded sands containing boulders, evidently rafted, in low valleys in the moraines; the valleys opening freely southward.

Staten Island District

In the region of New York City and southward where the waters were shallow and of diminishing depth, with fluctuating levels, it is to be expected that the amount of submergence can not be easily determined. But the erosional work and smoothing effect of standing water is evident.

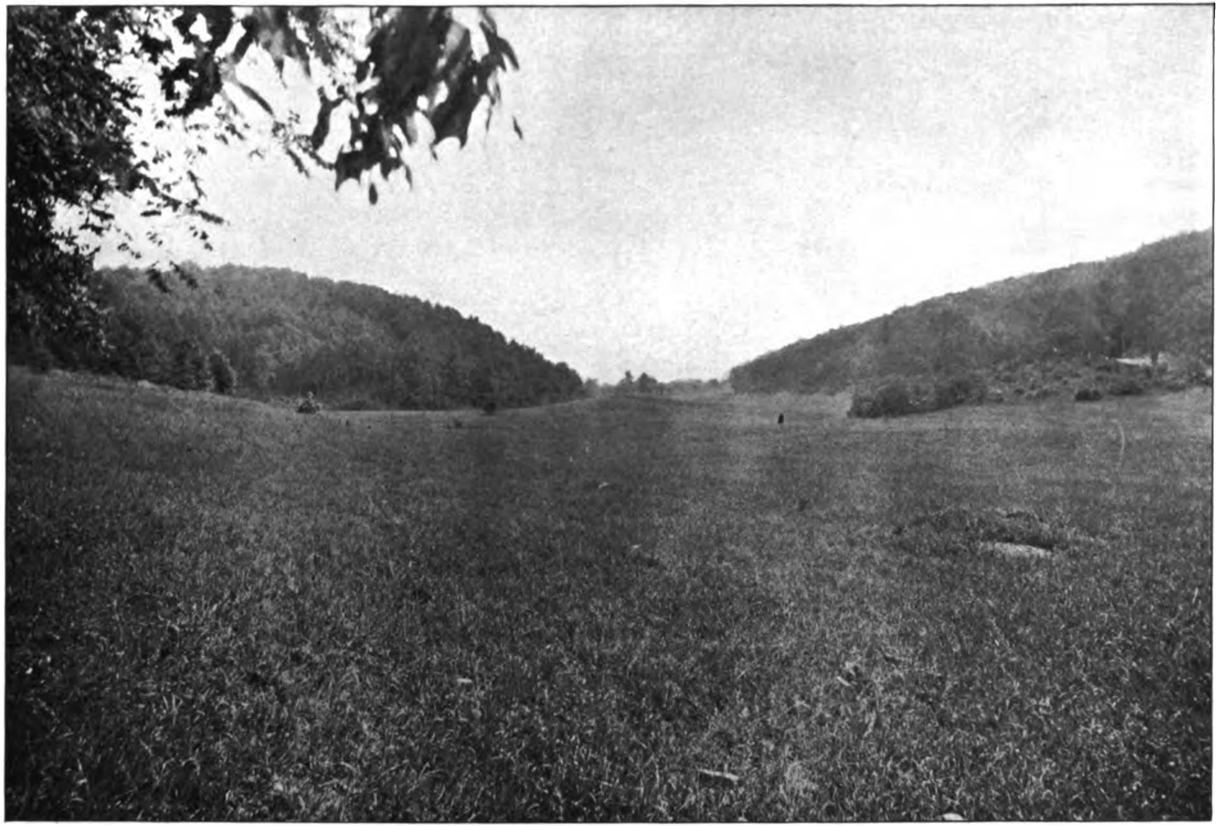
The writer has not made any study of Staten island or in New Jersey except along the northern boundary. Confidence has been placed in the published descriptions of Merrill (30–32), Ries (33–36), and Salisbury (41–43). West of the Palisades the lowlands exhibit clear evidence of water action since the ice sheet withdrew. Over the till, colored red by the debris of the Newark beds, lie abundant water-laid, yellow sands. In the Hackensack valley the evidence of standing water is clear up to the theoretic plane of submergence. The silt plains are found to the head of the Hackensack river, near the Short Clove and Long Clove. Professor Salisbury gives many references to the presence of water as the latest occupant of the territory.

Along the Hudson in the district of New York, and in Westchester county, the records of standing water were conclusive to the earlier students. In the last four decades the great expansion of commerce, business and building operations has obliterated many features. "Civilization" and "progress" have little care for such "impractical" matters as the geologic records. It has not been practicable for the writer to use the time that would be necessary to study closely this difficult area, but the testimony of the able men named above is regarded sufficient to prove the fact of recent submergence in the New York City district.

Hudson Valley

Tarrytown sheet. South of Ossining close study may find some remnants of deposits left, either by the glacial outwash or the land

Plate 13



Glacial stream channel, at Great Falls, 7 miles southwest of Catskill. Looking north, upstream, from the delta which was built at sea level. Present altitude 260–70 feet.

drainage, in the marine estuary, but the prevailing steep walls of the valley, with absence of heavy tributary drainage, has prevented the construction and preservation of conspicuous deltas. Of course, cliff-cutting and bar construction were negligible in such narrow waters.

But northwest of Ossining is one of the best deltas in the valley, and the finest in the present water. Croton Point, projecting 2 miles into the Hudson river, is the remnant of the heavy delta of Croton river. It is incontrovertible proof of high-level water in the Hudson valley since the glacier vacated. Some small remnants of the great delta are found in the level patches north of Ossining, but the greater part of the original delta has been cut away by the same stream that built it, aided by the tides and waves of Tappan Sea. The delta promontory represents the north flank of the original filling, and an evidence of the erosion is seen in the gap across the middle of the promontory.

The broad sand plain at the head of the promontory is definitely 100 feet altitude, by the topographic map; but this does not give the full height of the Hudson estuary. An examination of the ground in company with Professor Berkey finds that the summit water level is at about 120 feet. The 100-feet plain was under water, though wave-swept by the lowering (relative to the land) waters. Merrill made the usual mistake of taking the highest broad and conspicuous plain as marking the water surface. In some cases this may be the fact, but commonly not so.

On the west side of Haverstraw bay, at Haverstraw, West Haverstraw (Bensons Corners), and North Haverstraw, are thick clays and capping sands lying in an embayment of the broad valley. The summit altitudes of the sand plans agree closely with the profile in plate 10.

The northern portion of the low ground west of the Palisades, mentioned in the preceding chapter, is shown on this sheet.

West Point sheet. North of Verplanck the clay pits of an abandoned brick factory testify to the deep water of the Hudson estuary, and the capping sands are seen a mile northeast of the village. Here leveled sands and weak bars indicate the full height of the waters, about 125 feet.

Southwest of Peekskill for 2 miles the careful observer may see indeterminate inscriptions of the high waters. The state camp, over a mile northwest of Peekskill, is on a delta terrace with an altitude of 105 feet, some 25 feet inferior to the summit level.

Across the river from Peekskill is one of the most interesting

sand plains, unfortunately now mostly removed. Jones point has been for many years one of the sources of sharp sand and gravel used in New York City construction. Seen from across the river, or from the steamers, it yet shows the line of the gravel terrace banked against the Dunderberg mountain. The map is faulty and does not indicate even the remnant of the original plain. The north end and highest part of the plain is at about 130 feet above the sea. The southward slope of the summit shows clearly when seen from some distance. The structure and location of the gravel terrace, in relation to the mountain and valley, prove that it was a glacial delta. Its position rules out any possible land drainage. It was built by a glacial ice-border stream which flowed along the west edge of the ice lobe and which received the contribution of the land drainage north of the Dunderberg. The lower portion of the deposit is very coarse, containing thousands of boulders. The top and the southern end are finer, with the foreset and topset beds well displayed.

The geographical relations of the Jones point gravel terrace rule out, as explanation of the receiving water, any suggestion of glacial ponding alongside the ice lobe. The waters were the open Hudson inlet or estuary.

The constricted valley between Peekskill and West Point could not hold any large shore features; but minor features can be seen from the opposite side of the valley, or from the river steamers, and such have been measured at Fort Montgomery and Highland Falls.

At West Point the parade ground is the theoretic height for the summit level of the estuary, about 150 feet. But there has been so much grading and interference with the natural surface that precision in this locality is not attempted.

The terraces a mile northwest of West Point and across the river east of Cold Spring are contoured at 160 feet. As these lie in embayments of the valley walls they probably were marginal to the shrinking ice lobe, as described by Woodworth (82, pages 111–13), and were graded somewhat above the open waters to the south. The control of the waters on the West Point side must be the steep slope south of the point; on the Cold Spring side the channels of outflow control will probably be found opposite the point, a mile northeast of Garrison.

West Point, Schunnemunk and Newburg sheets. At the junction of these three quadrangles with the Poughkeepsie quadrangle two large and interesting deltas are found, one affording the site for the city of Beacon and the other for part of the city of Newburgh.

The southern part of Newburgh lies on the delta of Quassaic creek. The summit plain of the delta is well shown, both on the map and in the field, on both sides of the creek, with an elevation of 160 feet. The broader part of the delta plain is on the south side of the creek, underlain with scores of feet of blue clay. This clay has been extensively excavated along the river south of Newburgh and at New Windsor, and shows the usual succession; glaciated rock and compact till at the bottom, then the thick deposit of finely laminated blue clay becoming yellow toward the top, and a capping of sand and gravel. This will serve as an example of the valley deposits and the record of the succession of events since the ice occupation. The occurrence of huge boulders in the clays is evidence of waters laving the receding ice front.

Opposite Newburgh is the delta of the Fishkill, the larger part showing on the West Point sheet. The summit plain is on the Poughkeepsie quadrangle and carries the part of Beacon formerly called Fishkill. The altitude of the main street of Beacon is about 150 feet, at the west end. The map is wrong in showing the east end higher.

From Newburgh, or from the river steamers, the plain and terraces of the Fishkill delta are plainly seen. South of Beacon the delta stretches for 3 miles, and at Dutchess Junction and below are extensive brick works. Apparently the southward drift of the waters, aided by exposure to the northerly winds, swept the stream detritus southward. Denning point is a little remnant of the delta, a small imitation of Croton point.

Poughkeepsie sheet. Northward from Newburgh terraces of gravel and excavations in clay occur at several places. Woodworth indicates them as far as Marlboro (82, plate 5). The terraces have been so mutilated that their original form is uncertain. The terrace at Roseton, like many that will not be noted, was inferior in altitude, about 100 feet. At New Hamburg is the delta of Wappinger creek; but only the lower terraces lie here, for the reason that the summit level of the delta head forms the broad flats extending 2 to 4 miles above Wappinger Falls. A fair terrace and beach along the highway a mile south of New Hamburg, at 175 feet by the map, marks the summit level of the estuary. The smoothing effect of the waves is seen on the weak shales and the silt filling of the hollows west of Wappinger Falls, at about 170 feet.

East of Marlboro are flat-topped sand hills not properly shown by the map, but of inferior altitude. Northwest of the village, and north of the creek, by the railroad station, is an extensive gravel

plain, all in fruit farms. Mr Charles Young owns the point by the station and his house stands on the edge of the plain with altitude about 165 feet. The sand plain is 5 to 10 feet higher.

North from Marlboro are terraces and gravel and clay pits, especially on the west side of the valley. Many evidences are seen of the leveling work of waters, many being inferior in height as should be expected.

The eastern part of Poughkeepsie is on a sand plain built by Fallkill and Caspar creeks. The Vassar College campus occupies the southeast portion of the plain, with an altitude of 175 to 180 feet.

Rhinebeck sheet. Hyde Park stands on the north end of a terrace plain which stretches south 3 miles. The plain shows clearly on the map, which makes the height 200 feet, about the theoretic summit altitude. Some wave work may be seen along the highway in low, flat bars and swells of sand. Two creeks, one at each end of the plain, contributed material.

Rondout creek, the largest tributary of the Hudson south of the Mohawk, enters the Hudson at Kingston. One might expect to find here a large delta, but the deposition took place far up-stream, above Rosendale. However, detached plains and terraces record the summit level, about 220 feet. The broad sand plain at Rosendale, contoured at 220 feet, seems too high for its latitude as an estuary deposit, and may represent a distinct water body, glacial waters, or perhaps supergradation by the Rondout creek.

The village of Rhinebeck, two and one-half miles east of the Hudson, is located on a delta plain of the Landsmans kill. The plain, one and one-half miles in north and south extent, has been bisected by the creek, the village standing on the north half. The altitude of the flat plain is 210 to 215 feet, only some 15 feet beneath the profile. The existence of the village at this place is evidently wholly due to the plain.

The upper left corner of the Rhinebeck sheet shows a part of the plain of the Esopus creek, considered below.

Rosendale sheet. This quadrangle does not touch the Hudson river but covers features important in this study. We see here the Rondout river with its large tributary, the Wallkill; and the Esopus creek that joins the Hudson at Saugerties, on the Catskill quadrangle.

The Rosendale plains are contoured at 220 feet, over 10 feet above our profile. Assuming that the map is correct, excess in

height may not be more than allowance for supergradation of the large Rondout creek. The form and relation of the rolling gravel plain suggest that it was built by the Rondout and not by the Wallkill.

The Esopus creek curves across the northern part of this sheet. The mile-wide flood plain in the Kingston district lies much below the marine plain, and is apparently a plain of erosion, graded to the rock channel south of Saugerties (Catskill sheet). The higher plain which carries the main portion of the city of Kingston, with altitude up to 200 feet, represents the marine level. North of Kingston it is apparent that the Esopus has intrenched itself in a plain that was at least 60 feet higher than the stream, now 140 feet.

Catskill sheet. The theoretic marine summit along the Hudson on this quadrangle is about 240 feet, rising to 275. Sufficient records of the deepest waters are found, although no heavy deltas occur at the full height. The village of Saugerties lies on an inferior delta plain of Esopus creek, and Catskill is on a dissected lower plain of the Katskill.

The east face of the Catskill highland is a series of bare rock ledges, carved by south-flowing drainage, marginal to the waning ice lobe. The topography is probably the result of repeated glaciation with marginal stream work. The lowest channels of the latest glacial drainage must correlate with the estuarine waters. These significant features are found on the east face of the Mount Marion range of Hamilton sandstone hills, locally called the Hoogeberg.

At Dutch Settlement (Ruby P. O.) on the southeast corner of the Kaaterskill quadrangle, the stream channels terminate at something below 240 feet, with a gravel delta at 220 feet. South of Mount Marion P. O. the Plattekill has left a delta at 200 feet. Along the east face of Mount Marion stream cutting is distinct down to about 200 feet, and a delta heads at East Unionville (Veteran) at 220 to 230 feet. It is to be expected that confined streams along the ice margin, having torrential flow, will cut below the surface of the receiving water.

On the lower road to Mount Airy is a small delta at 240 feet, with correlating channel at 260. At Great Falls, near the county line, the Kaaterskill built a delta in the estuary with present altitude about 250 feet. A glacial channel (see plate 13) lies behind the hill at 260 feet, by the map. The delta of the Catskill is on the Coxsackie quadrangle, to be described below.

A mile south of Hudson city the marine waters built a heavy gravel bar, tailing from the south end of the hill on which the city

reservoirs are located. The house of Mr W. Tenbroeck stands on the bar, the head of which was made 275 feet by aneroid. The map contours the bar from 280 down to 240 feet. The profile (plate 10) makes 275 feet the precise altitude for the estuary at this point.

The smooth tract 6 miles east of the Hudson, stretching several miles past Livingston, Blue Stone and Manorton, shows the leveling and smoothing effects of standing water. Numerous kettles indicate that ice blocks of the glacier margin were buried in the detritus swept in by the land drainage from the east, perhaps aided by glacial outwash. The smooth kettle plain southeast of Livingston is contoured at 240 feet. The full height of the open estuary, 260 feet, is registered in the bare shales about the kettle area.

At Greendale, 4 miles east by south from Catskill, good bars were seen by the writer and Professor Chadwick at over 240 feet, by the map; and the top of the hill is planed at 260 feet.

Coxsackie sheet. This sheet shows the broad clay plains west of Hudson, traversed by the West Shore Railroad. Except for a space west of New Baltimore these plains extend the whole length of the quadrangle. On the north they join the great Mohawk delta, at Ravena and Coeymans.

The marine plane is about 280 feet at Athens, and rises to 315 feet at Coeymans. The clay flats are much below the summit plane; the "Athens flat" being contoured at 120, the West Coxsackie plains at 120 to 140, the New Baltimore at 200, and the Ravena at 200 feet. The deposits were laid in deep, quiet waters, and the material was probably contributed in larger part by the earlier strong glacial drainage through the Mohawk valley (164).

The west boundary of the estuary was here the bold face of the rock hills. The drift had been so fully removed from the highland by the ice-border streams that the later land drainage found little detritus to pile as sand or gravel, as topping for the clays, as we find southward. The land on the west was thoroughly swept by the glacial flow, and the glaciation and stream work, perhaps repeated, has given the decided allineation, north and south, shown by the map.

Only two streams were heavy enough to build deltas, and these are not in the open Hudson valley but up stream. One is the Catskill, extending from Leeds to South Cairo. This was years ago the subject of an admirable paper by Davis (37), in which he makes the altitude of the estuary waters at South Cairo about 275 feet. This proves to be the theoretic height, and the delta is

on the same isobase as the gravel bar south of Hudson, 10 miles distant and on the opposite side of the Hudson, with the same altitude.

The other and similar delta is that of Hannacrois creek, on the north part of the sheet. This has not been examined, but the map gives the height of the plains as 300 to 320 feet.

The west side of the Hudson on this sheet shows only the lower terraces of the detrital deposits in the estuary.

Kinderhook sheet. This displays the broad sand plains related to the Kinderhook river and its tributaries. The plain at Stuyvesant Falls is 200 to 220 feet, or some 70 feet inferior to the summit level. At Kinderhook the plain is 260 feet and over, or about 35 feet low. At Valatie, Niverville and Kinderhook lake the rolling flats are sandy and have the summit level, 300 feet. Flat, weak bars, characteristic of sand areas, occur northwest of Valatie at 300 to 305 feet. Weak cliffs are seen on the slopes east of Kinderhook and south of Valatie at the same height.

Westward toward the Hudson the detrital plains exhibit the terracing produced in the soft deposits by the subsiding waters. This feature is characteristic of the detritus-filled valley from here northward to Glens Falls, and very conspicuous in many sections.

Albany and Troy sheets. On the Albany map is seen the larger part of the great delta built by the Iromohawk river. The southern plains about Selkirk are 200 feet altitude, and the delta rises steadily to 350 or 355 feet at Schenectady. The delta and its genesis has been described by Stoller (87) and the writer (164), and further description here seems unnecessary.

North of Albany is a bold summit shore line. Along the Loudonville road a strong cliff extends for two and one-half miles in north and south direction, and the terrace facing it has provided a level stretch for a handsome boulevard. This is a favorite suburban residence district and popular drive. The south end of the beach is along the east side of a morainal tract, and the cliff curves sharply west about the south end of the hill between the Loudonville and the Shaker roads. In altitude the beach is about 340 feet.

On the Troy sheet inferior terraced plains are conspicuous along the Boston & Albany Railroad through Schodack town. The higher, rolling plains with irregular surface in the district of Schodack Center were probably laid in glacial waters, as noted by Woodworth (82, plate 8). The altitude of these plains, with kettles and rough surface, is 20 to 30 feet over the estuary level, 330 to 340

feet. The difference in the surface and composition of the plains above and below the theoretic plane is noticeable.

Shore lines are not conspicuous on the east side of the valley, but some cliffs are found on the slopes and terraces by the streams. A fair gravel beach occurs one-half of a mile northwest of East Greenbush, at 320 to 325 feet; another at the south end of Grandview hill with similar height. Along the road from a mile south of Defreesville to near South Troy the work of the higher waters is quite evident; 330 to 335 feet at Defreesville and rising to about 345 feet at South Troy.

Along both sides of the Hudson north and south of Albany the terracing of the valley walls is plainly shown by the map, and is very striking in the field. The history is clear; accumulation of detritus in the marine estuary at all stages from the highest, leveling and smoothing at all levels by the subsiding waters (land uplift), with later erosion by modern drainage.

Schenectady and Cohoes sheets. Besides the profuse estuarine deposits these two quadrangles hold several important special features. The Cohoes sheet displays in remarkable form the lower terraces on both sides of the river; the extensive delta of the Hoosick river; and a portion of the later filling by the Iromohawk river. The Schenectady sheet exhibits the deserted channels of the diverted Iromohawk, the north-leading one by the present Ballston Lake, and the subsequent one leading east by the Round lake and Anthony kill. A singular feature is the ice-block kettle holding Round lake.

The Hoosick delta has been described and mapped by Woodworth (82, plates 10, 24); and the Schenectady quadrangle by Stoller (87); while the history of the district has been recently described by the present writer, with a large map (93). The summit plains in the Hoosick valley are at Hoosick Junction and North Hoosick at 400 feet.

The interesting history of the Round lake district may be briefly epitomized as follows: The delta of the great Iromohawk river, the predecessor of the St Lawrence, headed above Schenectady during the time of maximum submergence, and the current flow was to the southeast. When the land uplift began and the estuary waters retired the river was diverted northward through the Ballston Lake channel; then building the sand plains by Saratoga lake. Further uplift with northward tilting eventually diverted the flow eastward through the Round Lake channel. This flow seems to have continued until the land here had lifted 200 feet of its total rise of 380 feet, as indicated by the stream work in the village,

which was diverted southward by the persistent ice block. Yet further land uplift diverted the river flow into its present channel.

If the record is correctly interpreted we have a correlation with Lake Iroquois history. The outflow of Iroquois continued here until the Covey outlet was opened. This implies that 200 feet of land uplift had taken place at Round lake when the ice front reached Covey hill, leaving 180 feet of rise in later time. It also gives an illustration of the persistence of buried ice blocks until exposure to the air. For further discussion the reader is referred to paper 93.

On the irregular rocky surface of the east side of the valley the summit shore features are weak; but they are found in the upper terraces of the Hoosick delta at Schaghticoke and Valley Falls, with an altitude of 380 to 385 feet. On the Schenectady sheet the summit levels are seen on the delta plains at East Glenville, at about 380 feet; and in the Mourning Kill delta, south of Ballston Spa, at 390 feet.

Saratoga and Schuylerville quadrangles. The Hudson river lies on the eastern half of the Schuylerville map but the western border of the estuary is mostly on the Saratoga sheet. On the latter sheet we see the great sand plain north of Ballston Spa, which was built by the glacial Kayaderosseras when it carried the glacial flow of the upper Hudson, the latter being forced south at Corinth (76). The full height of the plain is 400 feet by the map, which indicates that the rolling surface was a few feet over the static waters. Weak beaches and cliffs are found northwest and west of Saratoga Springs with a height of 400 feet and downward. The Cryptozoan ledge has been laid bare by wave action of the sea-level waters.

On the east edge of the Schuylerville sheet the summit plane of the estuary is seen in the highest terraces of the Batten kill delta, at Greenwich, 420 feet, and in cliffs southwest of the village. A splendid gravel bar lies 3 miles south of Durkeetown, at an altitude of 425 to 430 feet, only some 10 feet beneath the theoretic level. The bar mapped by Woodworth, 2 miles north (plate 12 of 82), is under 300 feet. Between these two bars are several good shore features, ranging from 400 feet down.

Many shore features are found on the hills northeast of Saratoga lake, which hills stood as a group of islands in the estuary waters.

The Batten kill drains a large territory on the east and in Vermont. It filled its upper valley with coarse detritus, at Cambridge,

Salem and East Greenwich, but the bulk of its finer burden was swept into the estuary and forms the extensive plains stretching for 7 miles along the east side of the Hudson.

Fish creek did not come into existence until the Saratoga district was lifted out of the static waters. With its small volume it made no delta of consequence.

As in the Schenectady-Cohoes section of the valley, the sand and silt plains show elegant terracing by the subsiding waters, at all levels from the summit down to 200 feet. The supposed river channels at Quaker Springs and Coveville are only the effect of wave work on the shales and delta stuff.

In the northwest corner of the Schuylerville sheet and west of Fortsville are sand plains at 426 feet, which are the delta built in the open estuary by the glacial outflow of the Hudson, past the east face of Palmertown mountain.

Further details and a map for this and the Glens Falls area will be found in paper no. 93.

Glens Falls and Fort Ann quadrangles. With this area we take leave of the Hudson river and valley proper, and have the col or divide between the Hudson and Champlain sections of the great valley.

The divide is a wave-smoothed stretch a mile wide and about 4 miles northeast of Fort Edward, with altitude about 150 feet. It never carried any river flow. The depth of the estuary over this divide was about 300 feet. From the time when the yielding ice front allowed the sea-level waters to pass beyond the divide into the Champlain section, the waters became the Hudson–Champlain estuary.

While the ice sheet lay against the Luzerne–Palmertown mountain face, southwest of Glens Falls, the upper Hudson and eastern Adirondack drainage was forced south at Corinth, through the Kayaderosseras valley, as described above. During the later phase of this flow the waters in the valley of Lake George were forced over into the upper Hudson by a pass 6 miles northeast of Luzerne, at an elevation of 760 feet (see Luzerne sheet). The delta from the George overflow is found north of Luzerne, the broad sand plain being 660 to 680 feet. Ten miles south, at South Corinth, is the outlet of the Luzerne lake, fed by the upper Hudson and the Sacandaga rivers, with altitude 630 to 640 feet (76).

When the ice front weakened on the steep face of Palmertown mountain the Lake Luzerne found lower escape into the estuary through the mountain pass where the Hudson now emerges from

the highlands. Here the upper Hudson waters built their delta, the great terraced sand plain covering all the southwestern part of the Glens Falls sheet and some of the Schuylerville. The summit altitude of the marine waters in the Glens Falls district is definitely shown by a series of strong gravel bars on the terrace east of the mountain, with a height of 440 down to 415 feet. The farmhouse of Mrs M. Hall stands on the terrace at 440 feet. The house of Richard Denton is on a broad bar, the third below the summit.

As the land slowly lifted the Hudson extended itself to reach the retiring waters, which carved the sand deposits into the cliff and terrace so well shown southwest of Glens Falls, at 400, 380, 340, 320, 300, 280 and 260 feet.

The latest deposits of the glacier in this district are found in the moraine and kames north of Glens Falls, at the foot of the highlands. During this phase of the waning ice it was faced by the waters of the George valley, occupying the passes either side of French mountain. The detritus from the land drainage was mingled with the glacial drift and outwash, together forming a morainal tract of cobble and sand, holding kettles and lakes. Glen lake and the neighboring "ponds" occupy the larger ice-block kettles. These sand-cobble tracts were partially leveled by the lowering glacial Lake George waters, down to about 460 feet, and below that more effectively by the sea-level waters. The rolling and knobby gravel tract north of Pattens Mills is typical of the deposit of mixed origin. The coarser, hilly area about Glen lake is more distinctly kame-moraine. The sand plain south of French mountain, at 520 feet; that about Rush Pond, at 500 and lower; and the kettle-plain at Bloody pond, west of French mountain, at 570 feet, represent the glacial George waters. The terraces in the valley southeast of French mountain at 450 feet, and all the lower plains and terraces are products of the estuary waters (Woodworth's plate 14).

The estuary, sea-level waters at their higher levels occupied the valley of Lake George, through the pass east of French mountain. Small deltas and other shore features will occur both sides of Lake George at and below the summit marine plane. This plane is about 450 feet at Caldwell and about 540 at Ticonderoga. The features are mapped in paper 93.

The Hudson-Champlain estuary lay over the western part of the Fort Ann quadrangle. Cliff cuttings in the shales have been noted west of North Argyle. No close study has been made of the rest of the area. Between Smith Basin and Fort Ann we see

the north portion of the narrow valley that was the long divide between the Hudson and Champlain; now cut by Wood creek. The only large stream is the Mettewee river. Its delta in the sea-level waters is apparently the filling at and above Granville, on the Vermont line.

Whitehall quadrangle. Sufficient examination has not been given to this area to speak with confidence of the features. Good shore phenomena must not be expected in such narrow valleys. The small deltas of the torrential streams will be the best criteria for the water levels. The marine altitudes are about 490 at the south edge of the sheet and about 530 feet at Stony Point, the north edge. The waters occupied the crooked valley of East bay and Poultney river, and passed far east to the Green mountains in Vermont (92).

The evidences of standing water are very clear from the trains of the Delaware and Hudson Railroad.

Champlain Valley

Ticonderoga quadrangle. On this area the estuarine waters were very irregular in shape, and the shore features about the hills on the eastern side of the lake have not been examined. The eastern shore of the estuary lies far eastward in Vermont, beyond Brandon and Middlebury, against the west flank of the Green mountains. The Vermont features are described in the Vermont report, paper 92.

On the west side of Champlain the shore features are well known, having been described by several authors, though not always with the correct interpretation (75–77, 82, 94).

The sand and clay plains representing inferior levels of the Champlain waters are conspicuous. They appear along the railroad from Baldwin to Ticonderoga, at 340 to 360 feet; north of Ticonderoga over a large area between the lake and the highland, at 260 to 280 feet; and especially in the embayment west and southwest of Crown Point, ranging from 200 to 480 feet. The theoretic marine plane lies on the west edge of the sheet at about 525 to 565 feet, or along the meridian of the lake at 530 on the south to 572 on the north.

This summit level of the sea-level waters is registered in the Crown Point district by gravel bars. The best series occurs 3 miles northwest of Ticonderoga and a mile north of Street road, on the east face of a kame-moraine, locally known as Sawyer hill. This locality was cited by Baldwin in 1894 (75, page 176);

described by Woodworth (82, pages 154–56, plate 15); and recently by Barker (94, page 12). In passing north from Street road it is seen that the south point of the hill is strongly wave-swept. At the forks of the road is a terrace at 350 feet; then we find a bar-cliff at 370, a good shelf-bar at 430 to 435 feet by the cemetery and house, a strong bar at 460 under the house of W. J. Crossman, a heavy cobble bar-terrace at 480, the wave-smoothed edge of the summit plain at 530 to 535, and a heavy summit cobble bar at 540 feet. The theoretic summit of the sea-level waters here is something over 550 feet. The rear side of the plain, next the bare rock face of the mountain, is a few feet lower than the front and smoothed by some stream flow past the ice margin that drained the Crown Point embayment. Shallow kettles lie on the plain and strong kettles at the edge. Woodworth gives a map of the district (82, plate 15) and thought that the standing water did not reach above 500 feet because of the unfilled kettles. But we have multitudes of kettles in deltas and river plains, and abundant evidence that drift-buried ice blocks may persist indefinitely as long as the area is under water. The kettles were not produced until the locality was lifted out of the estuary. The front of the plain is capped with cobble beaches which have been made discontinuous by the slumping in production of the depressions. The kettles have changed the surface as left by the waves, but have not fatally obscured the record. From the edge of the plain, 540 feet, down to the lower silt plain, 340 feet, the front of the kame-moraine is marked with bars and benches.

The deep embayment in the mountain wall, west and southwest of Crown Point, was partially filled with drift and stream detritus, largely of fine and clayey material. When the district was lifted these deposits were planed by the lowering waters, producing a conspicuous display of terraces and flat-topped areas. The evidence of standing water is found much above the marine plane, and perhaps represents glacial waters held in the embayment. The shifting outlet or control of the glacial waters is not determined, but probably was along the steep east face of Buck mountain. It is possible that there are unrecognized elements in the history of this region. The high levels are best seen west of Crown Point Center and at White Church, rising up to 610 to 615 feet.

Barker's map (94, no. 1) represents approximately the summit level of the marine invasion. His maps are correlated to imaginary outlets or flow-control which did not exist; and they attempt to represent distinct water levels which are not recorded either there

or elsewhere. Evidences of wave-work can be found up and down the valley at all levels, but water planes can not be postulated on a few detached features. Bar-building and cliff-erosion are controlled by variable factors, and except for strong and continuous beaches or through long distances the inscriptions are not reliable for levels. Of course it is probable that the rise of the land was not perfectly uniform, but there were no pauses long enough to produce distinct shores for any distance in the Hudson and Champlain valleys.

With reference to the assumed outlet or control of "Lake Vermont" at the divide northeast of Fort Edward, there is something more to be said. It appears that 200 feet of uplift had taken place at Round lake at the time Covey outlet became effective, and the ice front lay on Covey hill (see page 39). The divide is 31 miles farther north than Round lake, by isobases, and it should have been later in its uplifting. But even assuming that it did rise in company with Round lake, the 200 feet of uplift would have left it yet 100 feet under the sea (see page 40). And it is not reasonable to suppose that it rose the other 100 feet during the relatively short time that Covey outlet was effective.

It is possible that the divide rose 300 feet and was out of water, or above sea level, when the Champlain waters were permitted to mingle with the salt water of St Lawrence gulf.

In the valley of Lake George the shore features have not been seriously examined, but the proofs of standing water at various levels are evident. Theoretically, the highest levels should correlate with the outlet toward Luzerne, 760 feet. With some allowance for depth of water in the outlet it makes the water level at Caldwell about 780 feet, or some 460 feet over the present lake. At Ticonderoga the plane would be about 860 feet, or some 540 over the lake. The pass west of French mountain gave an outlet 185 feet lower. The marine plane is about 115 feet below the second glacial plane. The marine plane is estimated to lie at about 470 feet at Caldwell and 545 at Ticonderoga. It is for future students to verify and correct these three planes in the George valley.

Port Henry quadrangle. The most striking feature on the map is the vast clay plain east of the lake, with the Dead creek, representing the later work of the receding marine waters.

Snake mountain stood as an island in all the sea-level waters, and distinct summit shore features will doubtless reward careful search. With this wave-beaten height we take leave of shore fea-

tures on the east side of the Champlain valley, as they lie far east in Vermont (92).

At Port Henry is a narrow embayment or recess in the west wall of the Champlain valley which holds some excellent but puzzling records of standing waters. West and northwest of the village good delta terraces occur, related to Mill brook. The fair ground is on a plain at 600 feet, with wave erosion at the road corners. The cemetery is on another plain, the higher terrace being 640 to 650 feet. These levels are seen both sides of the creek valley. North of the fair ground on the east-facing slope are ridges and shelves that appear wave-shaped at 640 to 660 feet.

Southwest of the village, by McKenzie brook, a good series of bars occur on both the north and south roads. On the north road the topmost bar is under the house of A. M. Edwards, at 620 feet by the map. Four other close-set ridges carry down to about 550 feet, with terracing on the delta to 530 feet. On the south road the upper bar carries two houses at about 630 feet, with moraine beyond (above) it. In the field toward the brook good bars occur at 605 down to 560 feet; and terraces to 500 feet.

The reason for the above detail is the fact that these features lie much above the theoretic marine plane, which is here about 570 or 575 feet. The lower of the gravel bars falls within the marine level, but the highest is 60 feet too high. The topography of the valley wall and the small width of the embayment do not favor the existence of glacial waters with wave-efficiency to produce the bars; and the vertical succession of the bars through 70 feet rules out any definite outlet or fixed control. The series of close-set, well-developed bars is similar to those positively due to slow rise of the land out of water; and none of several explanations in appeal to nonmarine origin are satisfactory. It seems more likely that in this region, the east flank of the Adirondack mass, there has been an excessive uplift of 60 feet, with or without Postglacial faulting. The superior height of the Crown Point terraces, coupled with high features in the Peru region, to be noted later, lend force to this view. In such case our theoretic or datum plane does not represent quite the total rise in the Champlain region. The profile, plate 10, is drawn to connect with the summit shore at Covey hill.

About Westport are conspicuous lower plains, but the summit features have not been sought.

The estuary waters penetrated far inland up the valley of Bouquet river, which has a bend on this sheet, and the primary or full-

height delta appears at and south of Elizabethtown, 8 miles west of Westport. The village is built on the delta, with altitude 600 to 640 feet, and lies just above the isobase of 600 feet. This delta was the product of several streams uniting at this place. The superior altitude of the delta is due to the aggradation in a narrow valley far from the base level. The "Pleasant valley" section is graded to a lower level, 560 feet. This locality was made the subject of a paper by Ries (74).

Willsboro quadrangle. The profile levels along the west side of the lake rise from about 615 to 660 feet.

The lower plains of the Bouquet delta are conspicuous on the map, north and south of Willsboro. The coarser detritus of the river was dropped at the junction with the high-level waters far inland, that of the south branch at Elizabethtown, as already noted, and that of the north branch on the Ausable quadrangle 3 miles north of Towers Forge.

The hill 2 miles south of Willsboro carries elegant inferior bars on the summit and east face, from 300 feet down. Northwest of East Bouquet mountain clear evidence of standing water was seen along two roads up to a height of 620 feet. The theoretic height is about 625 feet. Examination of the area will locate many evidences of summit wave action.

Plattsburg and Dannemora quadrangles. On this area the summit shore features lie inland, with handsome display. The Plattsburg sheet shows the low ground built by the Ausable, Little Ausable, Salmon and Saranac rivers. But the south edge of this sheet covers the north part of the Trembleau mountain, which carries on its northwest slope a fine series of gravel bars below the summit of the marine flood. Woodworth maps these bars in his plate 21.

The Trembleau gravel bars lie one and one-half miles southwest of Port Kent, and 2 miles east of Keeseville. An east and west road crosses the plateau which carries the higher good bars. The highest bars, at about 590 feet, lie in weak form close to the steep northwest face of the mountain. This is 70 feet short of the summit plane, but the steep rock face shows its rinsing. On the road bars appear at about 575, 560, 545 and 530 feet. The northwest end of the hill is encircled by a series of bars to a lower level. The lowest feature is a cliff toward the railroad and near the border of the silt plain. Woodworth indicates shore features on the north and east faces of the mountain.

A mile southeast of Keeseville, on the northwest and north slope

Plate 14

Erosion cliff on delta sand plain. Two miles northwest of Harkness; on town line. Looking west. Altitude 640 feet.

of Prospect hill (Willsboro sheet) good evidences of wave work appear at 600 feet.

About Keeseville the Ausable river has laid down extensive gravel plains at 500 feet altitude, with terraces declining to Lake Champlain. The summit waters extended up the river 10 miles from Keeseville, to Ausable Forks, and broad plains between there and Clintonville, at 660 feet by the map, represent the higher delta.

The Dannemora quadrangle carries some of the strongest, handsomest and most convincing shore features of the marine-level waters of the State. As these are mapped in plate 8, detailed description will be unnecessary. It will be seen on the map that the bars have been plotted on the highways, but have not been traced across country, which gives the beaches on the map a broken and patchy appearance, untrue to fact.

Along the meridian of Harkness, Clark School, Beckwith School, and West Plattsburg the summit plane rises from about 660 at Harkness to over 700 feet at the north edge of the map. The deltas, glacial channels, and summit bars agree closely with this plane. The only discrepancy noted is the excessive height of some bars a mile southwest of Clark School which rise to 706 feet by the map, or nearly 40 feet above the profile (plate 10). The Harkness embayment was competent to hold broad glacial waters, but these bars are so closely connected with the marine shore that they are regarded in the same category as the high Port Henry bars.

Three classes of features are depicted on the map: (1) the ice-border drainage channels which terminate at or somewhat beneath the static waters; (2) the cobble and gravel bars of wave construction; (3) delta plains and terraces which occur at varied levels, from somewhat above the static waters to low levels in the subsiding waters (plate 14).

As is usually the case along all shore lines, the heaviest bars are somewhat below the summit plane, where the waves had sufficient accumulation of coarse material. The vertical series of heavy bars are found on stony slopes, usually so rough and stony as to be left uncultivated. Above and below the ground may be tilled. All the strong, close-set bars, not only on the Dannemora quadrangle but elsewhere, are on tracts of cobble or coarse gravel, commonly the deltas of glacial streams. Over ground immersed in sand the waves produce only smooth or rolling surfaces. On the areas of rising land, with open sea and free wave action, the construction of bars required coarse materials, at least for the basis or framework.

On the north edge of the sheet, 2 miles north of West Plattsburg, is the termination of an extensive cobble delta tract, built by glacial drainage along the high ground west of West Chazy (plate 5). This carries a remarkably fine series of bars, as depicted on the sheet, ranging from 684 down to 570 feet (plate 15). On this sheet the relative vertical position of the Covey Hill P. O. beaches is a smooth, sandy plain 2 miles northeast of West Plattsburg, with no decided shore forms. It illustrates the fact stated above, the absence of bars on sand plains. The Saranac sand delta illustrates the lack of bars on sands.

The Northern Salient. Covey Hill

Plate 5

Physiography. The northern promontory of the Adirondack highland is shown in plate 5, made up of the Mooers, Churubusco and Chateaugay sheets, with a strip of the Canadian Chateaugay sheet. This salient, wholly of Potsdam sandstone, terminates a mile north of the international boundary in an oval knob, locally known as Covey hill. The summit of the hill is given by the map as 1113 feet. It drops off steeply on the north, falling to 300 feet in 2 miles. The depression south of the hill, and one-half of a mile north of the boundary, has an altitude on the long swamp col of 1000 feet plus, by the map. The steep gorge on the east of the divide has been known as the "gulf." In relation to the glacial history this locality is perhaps the most critical in the State. The first geologist to recognize the significance of the Covey pass as related to the glacial waters was Dr G. K. Gilbert, who was the pioneer in glacial work, especially in New York.

The water parting, it will be noted, is on the west side of the promontory, which throws the larger territory into eastward drainage, the Chazy river. The Chateaugay river gathers the waters of the west slope. This is partial explanation of the larger volume of ice-border drainage on the Mooers quadrangle. Along the boundary a strip 2 miles wide drains into Canada.

As the Labradorian ice front backed away on this salient, the glacial outwash flowed freely away, east and west, making no decided channels near the crest of the ridge. On the west all the waters found their way into Lake Iroquois by the channels depicted on the Chateaugay sheet. On the east slope the waters came to rest in the sea-level Champlain estuary.

Mooers quadrangle. The drainage and static water features are

Plate 15

South edge of Cobble delta, 2 miles north of West Plattsburg. Looking north. Altitude about 570 feet

Cobble delta, built at sea level, now 700 feet above sea. One and one-fourth miles southwest of West Beekmantown.
Looking north, upstream.

Plate 17

Glacial stream work on nose of hill 4 miles south of Altona. Looking east, downstream. Altitude 1200 feet.

Plate 18

Highway on Potsdam sandstone; Altona village. Looking south. Characteristic "permanent improved road pavement" of the Altona district.

shown in a broad way in plate 5. This quadrangle was made the subject of a special paper by Woodworth (81), and was also covered in his more comprehensive Bulletin 84 (82). At the time of Woodworth's study no territory adjacent to the Mooers quadrangle had been mapped and definite correlation of features could not be made. It becomes necessary to republish the sheet in order to locate the summit shore line of the sea-level waters, to show the relation of features to adjacent territory, and to reveal graphically the sequence of events or the later Pleistocene history — the very latest glacial events of New York State.

Much study has been given to this area, long ago by Woodworth and later by the writer. Many visits have been made and some localities have been visited several times. Some of the features are so peculiar or equivocal or unusual in character that they were uncertain, and at first were misinterpreted. Some of the heavy tracts of cobble and boulder delta stuff had been regarded as moraine. The key to the history has been the determination of the summit level of the sea-level water, but much time and travel have been required to verify phenomena at critical points. Even now there are stretches of the summit shore line, rather inaccessible, far from deltas and of weak development, which are interpolated on the map. Future study will verify the shore line.

The position of the summit shore is determined by (1) wave-built bars; (2) higher terraces on deltas; (3) lowest reach of the ice-border drainage. The last is well displayed. Over large areas the Potsdam sandstone has been stripped of its drift mantle, and in the Altona region conspicuous channels have been cut (see Woodworth's illustrations). These areas of glacial drainage make the most conspicuous features of the map.

The sandstone in this region has an eastward dip and formed a hard floor, declining toward the receding ice front, thus favoring the stripping. Four areas of the "stripped rocks" may be discriminated on the map (plate 5). First, the Altona rocks, south and southeast of Altona (81, page 18; 82, page 161). This area is some 5 miles long by 1 or 2 miles wide. The upper margin on the east slope of Big Hill must lie under 1100 feet, and the lower limit is at Pine ridge, at the marine plane. Earlier glacial stream flow is indicated at higher levels south of Big hill. The Altona rocks are famous for their production of huckleberries (plate 18).

The other bare rock areas are partly on the adjacent Churubusco quadrangle. The second is the area southwest of Cannon Corners, called the Blackman rocks. The third is the Stafford

rocks, west and northwest of Cannon Corners, and traversed by the road from White School to the Rebideau farms. Fourth, Armstrong's Bush, an indefinite rocky area on the north edge of the map, which records the latest glacial stream flow in the State.

The heavy delta tracts of coarse materials are the product of the copious drainage noted above, of which two are of special note. The southern and earlier delta tract is the belt of bouldery, cobbly stuff, complicated with moraine piling, lying west of West Beekmantown and West Chazy, the effects of the Altona drainage. The later large and coarse deposit is on the west edge of the Mooers sheet at the north, and related to the bare rock areas on the west.

West Chazy district. In this district, the southern part of the Mooers sheet, is a remarkable display of summit shore features. The copious drainage from the Altona rocks supplied superabundance of very coarse material for work of the waves, while the ice built its frontal moraines as a foundation for bar construction. We have here a complex of features which will be misinterpreted and wrongly diagnosed by the geologist who has not had experience with such deposits. Here is the work of powerful torrential waters mingled with morainal material, and then more or less modified or reshaped by the wave-work of the highest static waters. The effects of the three agencies are mingled in varying proportions and it is often difficult or even impossible to discriminate the wave work, especially at the topmost line of the standing waters. In some cases the approximate summit is marked by wave embankments, but commonly the unmistakable bars are inferior to the summit level.

On the junction of the Mooers and Dannemora sheets the summit beach lies against a steep slope at slightly over 700 feet. Immediately west of the four corners, at the bottom edge of the Mooers sheet, is a heavy bar ridge with precise altitude (U. S. G. S.) 684 feet; and just east of the corners is another strong, conspicuous cobble ridge at 660 feet. The south termination of the delta tract is seen on the Dannemora sheet, plate 8. Northward on the north-leading road the delta gravels are shaped into indefinite ridges at about 700 feet. The photograph is plate 16.

One-half of a mile west by south from West Beekmantown is an isolated ridge, probably morainal, rising to 700 feet. About the south end of the ridge are heavy bars of boulder and cobble. On the east slope at the north end the ground is so rough that no one would suspect it to have been subjected to centuries of heavy wave action. It is a good example, that can be indefinitely multiplied, of the nonvalue of negative shore-line characters.

Summit of "Cobblestone Hill" in June 1912. The veneer of cobble laid by wave-work has been removed for construction of the concrete dam on the west slope, revealing a bowlder moraine as the mass of the ridge. Looking west of north.

Toward and at Shelter's Corners, northwest of West Beekmantown, the delta stuff is shaped into a fine display of bar ridges. Northeast of the corners the summit ridge is over 700 feet, and between that crest and the three corners below 12 to 15 bars may be counted in the drop to 580 feet. A mile north of Shelter's Corners is a long ridge carrying a road, and wave action is shown to the summit, 700 feet. Behind this ridge, on the west, is a smooth hollow, over 20 feet deep, which was apparently a channel for the latest flow when the ice front was building the ridge. Such smooth channels somewhat beneath the static water level are to be expected near the summit level where the glacier front was piling coarse moraine stuff in bold ridges, that the waves could not later demolish. Where there was little moraine drift, or drift of finer material, the frontal stream channels might be more or less obliterated.

One and one-half miles west of West Chazy on the east-facing slope the cobble bars are well developed. On the highway, the Basset road, 10 to 12 bars are counted in the fall from 500 to 400 feet. This lower series of bars has about the relative vertical position of the Franklin Center series in Canada, previously mentioned.

Cobblestone hill. This hill, described and illustrated by Woodworth (81, pages 32–35), is a good example of a moraine ridge modified in form by wave work. Lying detached, a mile north of the Basset road, and with conspicuous, bare, cobble bars crossed by the road, it was the subject of special notice. The top and east slope were handsomely shaped into bars of well-rounded cobble. The summit bar was 665 feet altitude, the lower bars ranging down to 580 feet. The summit was at least 50 feet beneath the highest stand of the Champlain waters. In recent years a reservoir has been built on the west of the hill and the summit cobble bar has been entirely destroyed for concrete material. This removal shows that the cobbles were only a veneer for a block moraine ridge (see plate 19). Cobblestone hill is not unique, but an example of the moraine ridges more or less modified by wave action. The occurrence of such a large quantity of uniform cobble on the detached hill is, however, a puzzle, and suggests that there may be some unknown factor in the history of the ridge.

The character of the Altona channels suggests a larger stream flow than merely that of the local waters, the Chazy rivers and the glacial outflow. The eastward position of the Altona highland seems to make it quite certain that the Altona channels carried the

earlier Iroquois, that through the Covey pass. Woodworth seems to have recognized this. This implies that the ice front rested against the Altona-Beekmantown highland after the ice had deserted the notch south of Covey hill. It also requires a glacial lake in the embayment west of Altona. There are evidences of standing water between Altona and Alder Bend, and north of Ellenburg Depot at 900 to 960 feet. We may refer to this water as the Ellenburg lake.

The later outflow of Iroquois produced the features in the Cannon Corners district.

Cannon Corners district. Here we find another remarkable display of Pleistocene features, fully matching that described in Altona. It includes vast areas of stripped rock, numerous river channels, enormous piling of cobble deltas over large tracts, and splendid development of high-level bars.

The areas of stripped rock have been named above. They are essentially a single area; that is, they represent the work of the same drainage, the Iroquois outflow, with falling levels as it washed the retreating ice front. The rocks are Potsdam sandstone, usually in irregular terraces, but sometimes steeply dipping. The inclined beds are well shown at Mitchell Rebideau's place, 2 miles southeast of Covey gulf. The stripped rocks may be conveniently seen by taking either of three roads: the indefinite and branching rock roads leading west from near the schoolhouse, three-fourths of a mile south of Cannon Corners; the road going west from Cannon Corners; and the road at the White School, a mile north of the Corners, leading to the Rebideau farms. The limits of the bare rocks are not perfectly defined on the map. The rocks are partially covered with scrub, bushes and huckleberries, and the precise mapping is not worth present effort. At a rough estimate, they extend some 6 miles north and south, and perhaps average a mile and one-half in width, or 9 square miles in area. The surface in general declines eastward, and the river flow which swept them clean migrated down the slope, clinging to the ice margin as the glacier slowly gave way. The lowest points of bare rock, and the termination of river work, lie along the north and south road from Cannon Corners to Shea's Lines. One exposure of rock is seen on the highway one-half mile north of the Corners, and another three-fourths of a mile south of the international boundary.

As the rivers reached the sea-level waters near the north and south line of the highway, it is along this road that we find the

Glacial stream channel on cobble delta. By White School, 1 mile northwest of Cannon Corners. Altitude about 735 feet. Looking north. The latest glacial drainage in New York, being the last of Iroquois downdrainage.

delta tracts of coarse stuff, formerly mistaken for moraine, and cobble bars in excellent development.

Passing south from Shea's Lines the road lies on a boulder moraine, at 760 feet, shown in plate 21. East and west of the low ridge are shallow scourways, the latest and lowest definite channels of glacial river flow in New York. The altitude of these channels is 740 feet. The road crosses the west channel three-fourths of a mile south of the boundary, and immediately south is seen some of the coarse delta stuff dropped by this, or the preceding flow, when checked by confluence with the marine-level waters. The White School, by the corners leading to Rebideau's, is in another river channel (plate 20), which has an altitude on the road of 720 feet, 10 or 15 feet beneath the marine plane. The delta stuff might be mistaken for moraine. South of the White corners the road rises slightly on the cobble delta, follows it for one-fourth of a mile and crosses another bare rock channel at 720 feet.

Strong cobble bars lie east of the road, the highest southeast of the White School at 735 feet. North of Cannon Corners the road crosses a series of six bars, the highest being 720 feet and the lowest, close to the corners, at 709 feet. This fine series of bars curves about the slope and parallels the road northward. Cannon Corners and the road leading west, up English river, are on very coarse delta. The surface appearance is that of a bouldery moraine, but the banks of the river cutting show its character as torrent deposit. South of Cannon Corners one-third of a mile is another series of cobble bars, in altitude from 720 down to 700 feet, but behind the schoolhouse and at the corners of a west-leading road is evidence of wave work up to 730 feet. These bars swing to southward and continue in good shape for over a mile along the slope of the delta on the east side of the road with an altitude of 720 down to 712 feet. For one and one-half miles southward the road lies on the delta, which suggests the amount of rock-rubbish that the glacial drainage swept off from the Blackman rocks.

The sand plain delta of the Chazy river, north branch, heads at 720 feet but declines to 660 feet 3 miles east, as shown by remnants. From this locality the marine shore turns southeastward, as shown in the map.

The series of lower beaches, the Franklin Center shore line, is very strongly represented on the north edge of the Mooers sheet, in 42 bars of coarse material spaced over one and one-fourth miles. Two miles southeast by English river the level is represented by numerous weak bars. Southwest of Sciota the shore appears in

good form, and again west of West Chazy. As already stated (page 19) this level of the lowering waters is not recognized distinctly south of the Mooers quadrangle.

The Covey channel. The form, dimensions and relations of the Covey pass are shown on plate 5.

The postglacial drainage history of this critical locality is not known in all its details. The locality is difficult to reach, far from highways and farther from any hospitable place of entertainment. It is a wild and romantic place; forest on the north wall of the channel, the roughest kind of rocky and swampy ground on the south side; on the west, at the head of the channel, a wide swamp and lake; and on the east, downstream, steep or precipitous rock cliffs and ledges, dropping down to the exceedingly rough lower ground. Attempts to reach the pass from the south were abandoned on account of the difficulty and limitation in time.

The channel proper is a splendid example of an abandoned river bed, over the hardest of sandstone; but it is unusual in the absence of any correlating delta. Below the normal channel we expect to find the deposited detrital burden of the current. Here is nothing of the sort. The low ground southeast is very rough, with no deposit of ordinary detritus. The only loose material within the grasp of the stream was whatever filling of drift the ice sheet had left in the pass.

It is more than possible that the recent history of the pass has been duplicated by glaciation earlier than the Wisconsin (Labradorian ice body), and this admission makes it uncertain as to how much of the form and character of the channel are really due to Iroquois outflow, and how much to earlier episodes of river work.

It seems probable that the earliest water across the col was tributary to a glacial lake, which we may call the Ellenburg lake, having its control on the Altona rocks. As the Ellenburg waters lowered, the Covey river cascaded over the Potsdam ledges and removed whatever detritus it had dropped in the preceding flow. Its latest cascading must have been the most vigorous and erosive. Another query is whether the rocks on the lower ground are partly glacial, rinsed off by the flood, or blocks plucked from the channel by the latest river, or by more ancient rivers.

The ravine or "gulf" below the upper broad channel, with its lakelets is evidence of plunging flow to low receiving waters, probably at the marine level. The ravine is not correctly contoured, for about midway between the head of the gulf and Covey Hill post office is an extensive filling, with piled rocks, and broad swamps.

Plate 21

Rock moraine at Shea's Line (international boundary) probably swept by latest outflow of Lake Iroquois. Looking north

The upper swamp was estimated as one-fourth of a mile long, with aneroid altitude 765 feet. The lower filling was made 740 feet, the marine level. The total length of the swamps and rock piles was thought to be nearly a mile. This may be regarded as the delta of the Covey river at the sea level, during its latest flow.

The rock bottom of the river channel is 1010 feet altitude on the divide. The limit of visible water work on both the north and south banks is about 1030 feet. The granite boundary monument on the south side of the ravine has an altitude of 929 feet at the base and 934 feet for the top. The altitudes given on the Churubusco sheet for the boundary monuments are all for "top of monument." On the Chateaugay sheet the altitudes refer to the base of monuments.

North slope and shore lines of Covey hill. The steep north and northeast slopes of Covey hill are mostly in forest, with only a few small clearings. A traverse was made down the north slope, but the line of strongest pressure and longest hold by the ice front must have been on the northeast face. The surface of the north slope is gradual and fairly smooth, such as would be expected of a strongly glaciated surface, down to 1010 feet, corrected aneroid. Below that occur rock ledges, benches and irregular terraces, such as belong to steep slopes cut by rivers held to their work by the forceful glacier.

From over 1000 feet down to over 700 feet the slope must have been eroded by the profuse waters of the Iroquois downdraining. Below about 720 feet, allowing 20 or 30 feet of cutting below static water level, the slopes were subjected to wave work of the sea-level water. Below the marine plane the steeper slopes show the ledges and rock piles due to wave action, while the moderate slopes carry embankments of wave construction.

The evidence of wave work at 740 feet is clear at all points where the plane has been examined. On the highway leading down the east side of the hill a well-defined cliff occurs at the critical level, and others at lower levels, especially at about 640 to 625 feet. On the north and south road, 2 miles west of the hilltop, the level appears in terraces at the angles in the road. Three miles farther west, by the four road angles, distinct cliffs show on the south, and delta sands by the Outarde river at 725 to 730 feet. The shore line can be traced along the road leading southwest; and on the road leading northwest, 2 miles southwest from Franklin Center, strong bars cross the road from about 725 down to about 660 feet. At Frontier the shore passes back into New York, where

good bars lie at 700 to 730 feet. These features are indicated on the map, between which the shore line has been interpolated, being mostly in forest and not examined. Future study will discover many good features. It should be emphasized that this shore line lies with identity of character and altitude on both flanks of the Covey promontory, in both the Champlain and Ontario basins.

The Franklin Center-Covey Hill post office beaches. This strong shore line, 215 feet beneath the marine summit, was formerly regarded as the marine summit (81, 82). It carries a splendid set of bars at all points about the Covey salient in Canada. Lying low on the slopes it probably represents an accumulation of coarse detritus by the rinsing down of 200 feet on the higher slopes, and perhaps some kame-moraine at this level. Around the north side of Covey hill the wave work had been mainly erosional from the summit level down to the Franklin Center level. At this lower plane the off-shore depth and other relations were such that the work of the waves became chiefly constructional. The exceptional development of summit bars in the Cannon Corners district was due, as already stated, to the abundance of coarse delta stuff from the inferior downdrainage of Iroquois.

The 215 feet interval between the two strong shore lines so prominent on the map is rather misleading. Intermediate features exist, and the scanty representation is due more to lack of observation than to actual absence of beach phenomena. Attention has been chiefly directed to the two series of bars.

The unusual development of the Franklin Center bar series might be regarded as the record of an episode of much slower land uplift. But as the shore is not clearly recognized southward beyond the area mapped in plate 5 or southwestward beyond Lawrenceville, on the Moira quadrangle, it must be explained as due to exceptional local conditions. The possibility is recognized, however, that in the progressive wave uplift of the land this district might have risen at first with relative rapidity, for the 215 feet, and then more slowly.

The location and character of this shore is sufficiently shown in the map. Below the upper bars, 525 feet, the beach phenomena are abundant at all declining levels where conditions were favorable. A fair set of bars lie on the Chateaugay sheet, and a remarkable series on the north edge of the Mooers sheet. The shore also appears along English river, and west of West Chazy; but southward on the Dannemora sheet its place is occupied only by smooth or rolling tracts of sandy soils, with no bars.

Glacial stream channel, 3 miles southwest of Chateaugay. Looking east, upstream. Altitude 1120 feet.

Bar Succession

LOCALITY	NUMBER OF BARS	HORIZONTAL DISTANCE, IN MILES	VERTICAL RANGE, IN FEET	AVERAGE INTERVAL, IN FEET	GREATEST SINGLE INTERVAL IN FEET
		Bars of the marine summit			
Irish School	8	¼	40 (730–690)	5	10 (middle)
Armstrong's Bush	6	¼	20 (730–710)	4	
North of Cannon Corners	7	¼	20 (725–705)	3	10 (at top)
Cannon Corners School	6	¼	25 (730–705)	5	10 (at bottom)
Shelters Corners	15	½	120 (700–580)	8	
Beartown	13	....	115 (684–569)	9	
Peru	9	½	80 (590–510)	9	
		Bars of the Franklin Center series			
Franklin Center	18	¼	112 (525–413)	6	
Stockwell P. O	13	½	135 (510–375)	10	12
Covey Hill P. O. north	16	1	210 (530–320)	13	23 (at bottom)
Covey Hill P. O., east	18	1	131 (523–392)	7	13 (at top)
South of boundary	42	1¼	160 (525–365)	4	
Basset road	12	....	100 (500–400)	8	

Bar succession. The above tabulation clearly proves that the production of embankments or bars along shore lines is not wholly a function of duration, or length of time for wave work at a fixed level, but that it depends on a combination of physical shore conditions. Chief of these factors is an abundance of coarse material, as boulders and cobble, which the waves can throw beyond their future grasp. This is proved by the large development of bars on cobble deltas and their absence at the same level, in near localities, on sandy tracts. Other evident conditions must be sufficient breadth and depth of water for efficient waves and shore currents, and favorable shore topography for piling the detritus.

The succession of bars with close spacing through large vertical range can not be produced in water of fixed level, in relation to the land, nor in rising levels. They are the product of slow and steadily falling levels. Marginal glacial lakes do not have the requisite conditions. The series of bars shown in the accompanying maps, for Lake Iroquois and the sea-level waters, can be constructed only by the slow uplift of the land out of the waters.

St Lawrence Valley

Chateaugay quadrangle. The striking feature of this map (plate 5) is the Iroquois shore line with its correlating glacial drainage channels (plate 22). This is well marked by deltas an dweak bars, but fading northeastward on the Churubusco and Canadian sheets toward the second outlet at Covey pass. In this district the marine

shore has much stronger development of bars than the Iroquois. The heavy representation on the map of the lower, Franklin Center, series is somewhat misleading, as these bars are only gentle rolls or swells on the plains away from the stream deltas. Near North Burke, however, is a kame-moraine which has been shaped into bold ridges. Two views of the Chateaugay delta in Lake Iroquois are given in plates 23 and 24.

Malone quadrangle. The shore lines and deltas are well shown on the map, and do not require much description. The lower marine deltas lie in position to represent the Franklin Center shore. Below this broad sand and silt plains extend down the Trout and Salmon rivers to Canada; but are not colored on the map.

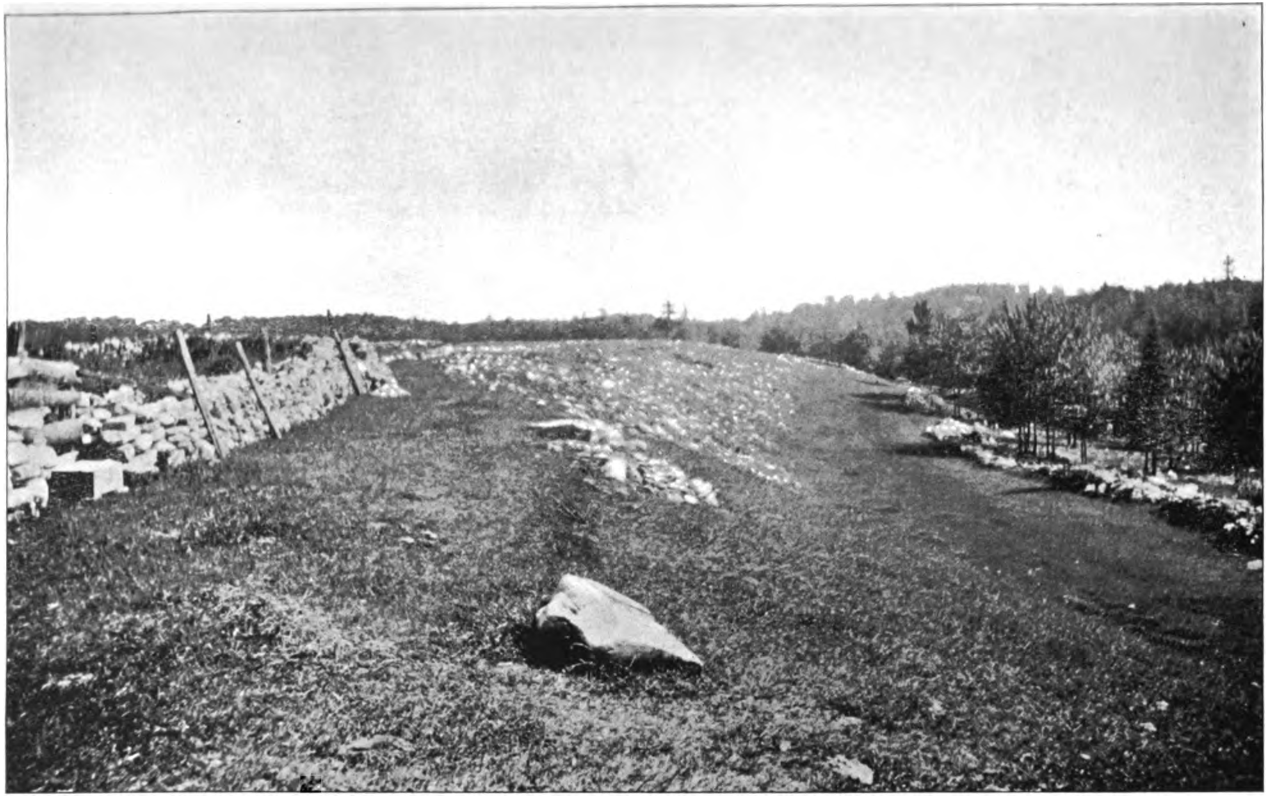
The head of the Salmon river delta in Lake Iroquois is represented in boulder masses some 7 miles up the river ravine at Chasm falls. Remnants of the delta are seen south of Malone in the reservoir and other gravel hills, but the vigorous Post-Iroquois erosion has swept away most of the Iroquois delta and redeposited it downstream at the sea level, making the massive sand plain north of Malone.

On this sheet no attempt has been made to map beaches below the marine summit. The marine shore lies across the southeast corner of the Moira quadrangle, which is not included among the maps of this writing. The most conspicuous feature on the Moira quadrangle is a strong shore south of Brushton and Moira and passing through Lawrenceville, in the approximate position of the Franklin Center shore line. So far as observed, this is the last clear representation of that lower shore, going to the southwest.

The area south of the Moira and east of the Potsdam quadrangles has not been mapped, but the shores lie across the northwest corner of this unnamed sheet in strong shape. The Iroquois delta on the Deer river is at Dickinson Center; and on the east branch St Regis, at Nicholville. Northwest of Dickinson Center are good summit bars of Iroquois, and one and one-half miles southeast of Nicholville are strong boulder bars, lying obliquely across the road with moraine surface behind them. This will give a good figure for the Iroquois shore when the topographic survey is made. The marine plane is shown by bars and delta at Fort Jackson, on the St Regis river, east branch.

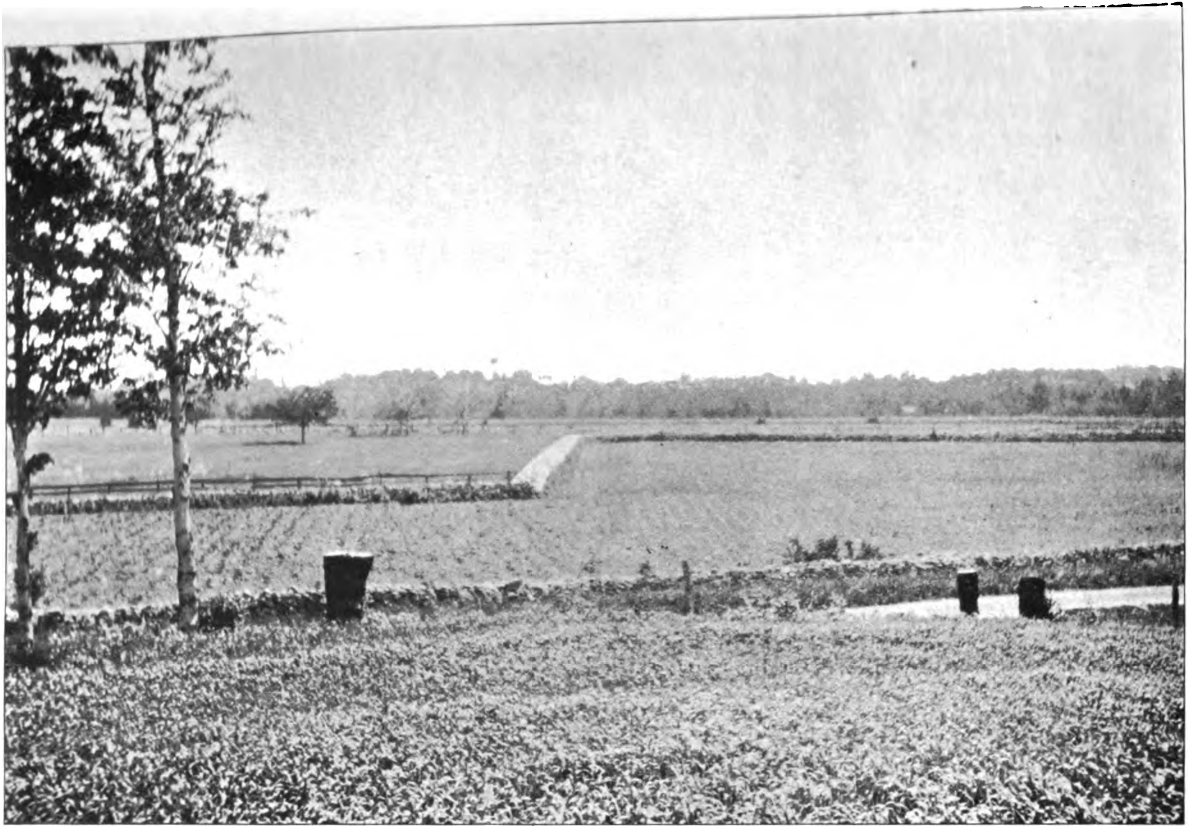
Potsdam quadrangle. This quadrangle has been examined with care, and with the assistance of Prof. George H. Chadwick. Two large rivers cross the area, the west branch of the St Regis, and the Raquette, and they have left heavy deltas at the Iroquois and

Plate 23



Summit of Chateaugay River delta in Lake Iroquois. One and one-half miles southwest of Chateaugay village. Looking north. The river gorge on the right.

Plate 24



Cobble plain near the head of Chateaugay River delta in Lake Iroquois. One mile southwest of Chateaugay village. Looking east across the north-sloping plain.

the marine levels. The map (plate 7) shows the standing water features.

A good development of bars, with clear relation to the drift surfaces, gives fairly exact altitudes. One occurrence is a mile northeast of Parishville, where three elegant bars have altitude, 928, 905 and 885 feet. At Colton and the Clafin School the strong shore features have not been measured.

The marine shore is well shown by weak bars and points of deltas northeast of Southville, at 600 to 615 feet, and west of Hannawha Falls by cliff and bar.

The Franklin Center stage is only suggested; but detached beaches are found at many levels inferior to the summit.

The delta at Allens Falls, on the St Regis, appears to have been built during the downdraining of Lake Iroquois.

Canton quadrangle. The details on the sheet have been studied, mainly by Professor Chadwick, and as he has projected a paper on the Pleistocene geology, the map is not included here. Now it will be sufficient to say that the Iroquois shore merely touches the southeast corner of the sheet; that the marine shore crosses south of Crarys Mills and Langdon Corners, with construction of weak bars on the northwest face of Waterman hill, and a heavy delta on the Grass river at Pyrites.

Russell quadrangle. On this area the Iroquois waters reached far up the Grass River valley, among the Adirondack hills. The plains at Burns Flat and northward, on the east side of the quadrangle, probably represent the delta of the Grass.

Wave erosion of Iroquois is well shown on the hills about West Pierrepont, and on the hill at Stone School, a mile southwest. Cliffs and bars appear on the northwest and the south faces of Kimball hill, north of Russell. An excellent development of beaches is found on the Hatch (Hamilton) hill, over a mile southwest of Russell. These have been measured with sufficient precision. The summit bar of Iroquois is here 850 feet, and bars range down to 815 feet. The vertical range of 35 feet appears to represent the amount of land uplift at this locality during the life of Iroquois.

The Oswegatchie river crosses the southwest corner of this quadrangle, and its delta is about South Edwards and Pond Settlement. The theoretic altitude here is 780 feet for the closing level, and the features range from 826 down to 780 feet, a vertical range of 46 feet.

The marine shore lies on the northwest corner of the area, north

and south of the village of Hermon, which is built on a terrace of the Elm creek delta. The summit shore line passes through the east edge of the village, with altitude 520 to 525, the theoretic figure. The extended plain lying for miles along the upper valley of Elm creek, from Fairbanks Corners to Scotland School, appears to be due to waters held in by rock control south of Marshville. The marine delta of the Grass river is at Pyrites, on the Canton quadrangle.

Gouverneur quadrangle. The Iroquois level appears in the southeast part of the area, in the higher sand plains about Fullerville Ironworks, at about 780 feet. These plains are the north part of the delta of the west branch of the Oswegatchie river, which extends 7 miles south to Harrisville, on the Lake Bonaparte quadrangle. The narrow waters entangled among the hills could not be expected to produce distinct shore features.

The lower plains north of Fullerville, 700 feet, and those at Edwards, 660, seem to have been due to pondings of the Oswegatchie while it was cutting the rock gorges at Hyatt and Emeryville.

The marine shore lies diagonally across the area from the northeast to the southeast corner, with altitudes of 525 down to 480 feet. The Oswegatchie delta begins at Hailesboro, 2 miles southeast of Gouverneur, and the lower levels are the extensive plains at and above Gouverneur. The delta plains are fine material, as the coarse detritus had been dropped above the rock barrier.

The Gouverneur sheet shows strikingly the singular topographic character of that region, a complex of smoothed rock knobs and ridges, with intervening smooth silt plains. The latter are the product of the sea-level waters which rinsed the drift off of the knolls and hills and spread it out evenly in the hollows. The clean-cut horizontal line of contact between the silt plains and the steep rock slopes is characteristic of the submarine silt plains in New York and Vermont. The traveler on the Rome, Watertown and Ogdensburg branch of the New York Central Railroad may see this feature all the way from Canton south to Keenes. Southward through Antwerp the road lies above the marine plane.

Five miles northeast of Gouverneur and 2 miles south of Richville, by the Cole School, is a good display of summit marine cobble bars on some drift knolls. The bars are from 516 feet down. Evidences of wave work on the slopes is common in this district.

Lake Bonaparte quadrangle. The Iroquois waters passed up the Oswegatchie valley as a deep embayment to Harrisville, where the

delta seems to head. The waters lay here and among the detached hills at an altitude of 745 feet for the closing phase, but the plains recording the earlier and uplifted levels are about 770 feet. No study has been made of this area.

The marine waters did not reach this quadrangle.

Antwerp quadrangle. On the southern part of this area lies the greater mass of the huge delta of the Black river built in Lake Iroquois. The head of the delta lies south, up stream, on the Carthage quadrangle. The theoretic altitude for closing Iroquois in the district of the Great Bend is 700 feet, and the broader plains are contoured at 700. The higher plains, about Carthage are up to 740 feet. The history of the waters in this region is told in publications 162 and 163.

The marine waters did not reach this area; but had irregular extension among the hills northward, on the Hammond quadrangle.

The accompanying map, plate 4, gives the approximate location of the shore lines on the quadrangles which are not reproduced for this writing.

Ontario Basin

Lake Iroquois. West of the St Lawrence area, above described, the beaches of Lake Iroquois and of the sea-level waters have been described and mapped in former publications. The beaches of Iroquois were the first of the ancient shore lines to be distinctly recognized as such, and are too well known in the Ontario basin to require extended notice here. The more important papers have been listed in the bibliography. The more recent maps are in the following papers:

In 154 of the appended list, plate 19 is a map of the lake south and west from Watertown; with description of the strong shore from Watertown to Richland, pages 104–12, and tabulated details in plates 9 and 10.

In 152, a good map by Coleman, with description of the Canadian shore.

In 163, a part of the Black river delta is shown in plate 44, and described in pages 136–72.

In 164, plate 17 shows the early stage when the lake had reached its full westward extent, as a narrow stretch of water along the south front of the Ontario glacier lobe. Plate 4 in this paper is a detailed map of the shore line in the Watertown region, from Carthage to Adams, with the channels of tributary glacial drainage.

Accompanying this paper, plate 1 shows Lake Iroquois at its greatest expansion, just previous to its extinction; plate 4 shows

the approximate location of the shore north of Richland; and plates 5, 6 and 7 depict the northern shore in New York in detail. For future mapping there remains only three unpublished sheets, in part; and the short stretch from Rome to Richland.

A very brief outline of Lake Iroquois history may appropriately close the description. The lake originated at the margin of the waning Ontarian lobe of the latest ice sheet when the ice uncovered the southeast part of the Ontario basin, the low ground at Rome and Oneida lake. An early stage, when it reached westward only to about Lyons, is mapped in plate 41, paper 160. As the ice lobe gave way the lake extended itself westward until it was a narrow belt of water, laving the south front of the glacier, the whole east and west extent of the Ontario basin, as mapped in plate 42, of 160; and plate 17, of 164.

As the Ontarian ice lobe diminished the lake increased, and inserted a tongue of its water northeastward, between the ice margin and the foothills of the Adirondacks. The greatest extent and area of the lake was attained while the lake had its second outlet at Covey pass, above described and mapped in plate 1.

The lake came to its extinction when the ice barrier on the north slope of Covey hill weakened, and melted back to a height beneath 1030 feet, or the height of the Covey river. Then the waters were permitted to drain down to sea level, and to become part of the Hudson-Champlain estuary, shown in plate 2.

Gilbert gulf. That the low altitude of the northern land at the time of disappearance of the latest ice sheet must have allowed oceanic waters to occupy the St Lawrence and Ontario valleys has been recognized many years. As long ago as 1898 F. B. Taylor mapped the Champlain sea as extending into the Ontario valley (136, page 73).

Dr G. K. Gilbert was the first geologist to recognize the beaches produced by this extension of sea-level waters (11, page 59), and called them the Oswego shore line, although they do not quite reach to Oswego.

In 1905 the writer briefly described the beaches in the southerly stretch between Oswego and Clayton, and added sketch maps of most of the distance (157, pages 712–18; figures 1–3); and took the liberty of naming these marine-level waters after Doctor Gilbert, in admiring recognition of his leadership in the study of the New York Pleistocene.

In 1910 the writer extended the mapping of the Gilbert gulf

Plate 25

Cobble bar on the shore of Lake Iroquois. One-fourth mile north of Farr's and 3 miles east of Watertown. Upper view looking northeast; lower view looking southwest.

shore as far northward as Alexandria Bay and Redwood, in a partial way, as the beaches are detached and mostly weak (163, plates 44–47; pages 136–72). The most important series of bars is on a moraine tract 2 miles north of Lafargeville, with summit altitude about 440 feet. In this district of horizontal rocks, low relief and clay plains; or farther north, with glaciated granitic knobs and silted hollows, the waves found little material and poor conditions for leaving their inscriptions.

SUMMARY

It seems possible that the Pleistocene history of New York State includes more than one ice invasion, or glacial epoch; but this writing deals with only the records of the latest ice sheet, and specifically with the waters that occupied the low valleys as the ice body melted.

When the Labradorian ice cap was disappearing, the land which had been beneath the ice sheet was much lower than at present. The amount of the depression seems to bear quite direct proportion to the thickness and weight of the ice burden. The measure of that depression is found in the Hudson-Champlain valley, and about New York City and over Long Island, in the shore phenomena left by the sea-level waters that took possession as the ice vacated. The amount of the land uplift is shown in the maps, and for the Hudson-Champlain valley in the diagram, plate 10.

In the St Lawrence-Ontario valley the amount of postglacial rise of the land is found by the amount of deformation, or northward up-tilting of glacial lake shore lines, which must have originally been horizontal. The shore line of Lake Iroquois has been deformed 668 feet, and bodily lifted 72 feet more, which gives a total rise at Covey hill of 740 feet, the same as the altitude of the marine beaches at that point. The diagram (plate 11) shows the tilt of the St Lawrence beaches.

The records of the sea-level waters in the Hudson-Champlain valley cover all of the long time involved in the waning and disappearance of the ice sheet, from the moment of its greatest extent to the time when it passed entirely off the State. But the glacial records in the St Lawrence valley cover only the latter part of glacial time. For this writing the history of the St Lawrence valley is only that of Iroquois and Post-Iroquois time.

The history, in brief, is as follows. The sea-level waters continuously laved the receding front of the glacier as it retreated up the Hudson and Champlain depression. Large glacial boulders in

the clays are proof of this. When the margin of the ice sheet receded, on the high ground north of the Adirondacks, to the international boundary, it uncovered a low notch, the Covey pass, which permitted the outflow of the glacial waters of the Ontario-St Lawrence basin, Lake Iroquois; and from this time the St Lawrence waters were tributary to the Champlain valley, instead of, as formerly, to the Mohawk-Hudson. At that time the Covey outlet was 740 feet lower than today, and only 290 feet above the sea.

With further recession of the ice barrier on the north slope of Covey hill, Lake Iroquois was drained down to sea level. The Hudson-Champlain estuary then passed westward around the Covey salient and occupied the St Lawrence basin. The altitude relations of Lake Iroquois and the sea-level waters are tabulated in plate 12.

The postglacial rise of the land was by a wave uplift, progressive from south to north, following the removal of the ice burden. The rise was laggard or dilatory, and it appears that no appreciable rise occurred at any point in the Hudson valley while the ice lay on that point. But it seems more than possible that the uplift wave overtook the receding ice front in the Champlain valley; and that a relatively small rise took place at Covey hill while the ice held Lake Iroquois to the Covey outlet. This would account for some shore features in the districts of Crown Point, Port Henry and Peru somewhat above the profile shown in plate 10. In such case the bars at Covey hill, 740 feet, do not give the full amount of glacial depression and postglacial uplift. The maps and profiles do show the positive minimum of recent diastrophism.

It is recognized that there may be complications in the Pleistocene history, and that the present altitude of the upraised water plane is only the final or average result of any up and down land movements, and any variations of the sea level; the arithmetical sum of all the plus and minus elements. But it appears that such complicating factors would probably increase the record of land depression and subsequent rise, instead of reducing it. To the degree that the ocean level was lowered by removal of water to build the ice caps, the ancient water plane was so much beneath present ocean level. The present height of the summit plane above the sea must be only the excess of land uplift over any rise of the ocean surface.

The gravitational pull on the sea level by the ice body at the attenuated margin of the valley lobe is thought to have been a negligible factor in the New York district; and probably so at all

other localities when the receding and relatively thin ice margin was passing off.

The evidences of marine submergence of Long Island and the Hudson-Champlain valley are briefly stated. The lack of marine fossils in the Hudson valley, and of wave-built embankments on the sand plains, are explained. A running description is given of the summit shore phenomena from New York City northward; at and around Covey hill, and through the St Lawrence valley.

The summit shore features on the Vermont side of the great estuary has been recently published (92).

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The literature of the Ontario basin can not be entirely separated from that of the Great Lakes area. A list of papers relating to the glacial waters of the upper Great Lakes, up to the year 1907, is given by Goldthwait in no. 23. In no. 82 Woodworth gives an extended list of the older literature, to 1905, with special reference to eastern and northern New York.

Eastern Canada is in its geography and glacial history so closely connected with the Champlain-St Lawrence basin that some papers describing Canadian territory are included.

Many papers relating to New England geology have direct bearing on the diastrophic problem, but only a few papers concerning the Connecticut valley are here included.

For convenient reference the titles are arranged in six groups, with a few cross references. Within each group the order is chronologic by authors.

A General; theoretic; land deformation
B Lower Hudson district
C Long Island
D Connecticut valley
E Upper Hudson, Champlain and eastern Canada
F Upper St Lawrence, Ottawa valley and Ontario basin

A General; Theoretic; Land Deformation

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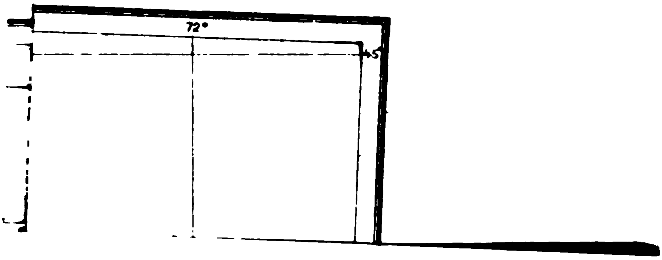

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Published monthly by The University of the State of New York

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The University of the State of New York
New York State Museum
John M. Clarke, Director

GEOLOGY OF THE LAKE PLACID QUADRANGLE

By WILLIAM J. MILLER

WITH A CHAPTER ON THE PLEISTOCENE GEOLOGY

By HAROLD L. ALLING

ALBANY
THE UNIVERSITY OF THE STATE OF NEW YORK
1919

M119r-N18-1500

The University of the State of New York

Science Department, November 16, 1918

Dr John H. Finley

President of the University

Sir:

I beg to transmit herewith and to recommend for publication, as a Bulletin of the State Museum, a report entitled *The Geology of the Lake Placid Quadrangle,* which has been prepared, at my request, by Prof. William J. Miller.

With this manuscript are also transmitted the necessary maps and illustrations.

Very respectfully yours

John M. Clarke

Director

Approved for publication, November 16, 1918

President of the University

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GEOLOGY OF THE LAKE PLACID QUADRANGLE

By WILLIAM J. MILLER

WITH A CHAPTER ON THE PLEISTOCENE GEOLOGY

By HAROLD L. ALLING

INTRODUCTION

The Lake Placid quadrangle[1] comprises a territory of approximately 214 square miles in the northeastern portion of the Adirondack mountains. It is bounded by latitude lines 44° 15′ and 44° 30′, and by longitude lines 73° 45′ and 74°. More than two-thirds of the area of the quadrangle lies in Essex county, while the remaining (northern) portion lies in Franklin and Clinton counties. Lake Placid, Newman, Keene, Upper Jay, and Wilmington are the principal villages. Haselton has but a few houses, and Franklin Falls, once a village of 30 or 40 houses, now has but two residences and an electric power plant. Only one railroad enters the map limits, this being the Adirondack branch of the Delaware and Hudson, which reaches 1 mile into the quadrangle to Newman near Lake Placid. A new state road crosses the quadrangle from west of Newman, through the Wilmington notch, the village of Wilmington, and thence eastward. Another state road passes through Keene and Upper Jay.

Lake Placid and immediate vicinity is one of the greatest of all Adirondack summer resorts. There are several large hotels and many smaller hotels and boarding houses which accommodate

[1] See map in pocket of back cover of this bulletin.

thousands of people during the summer season. Of late years Lake Placid has enjoyed considerable popularity as a winter resort. Thirty-five or forty years ago there was great activity at East, Middle and West Kilns where charcoal was made for use in iron furnaces at Black Brook a few miles to the east.

In 1842 Prof. E. Emmons published his Survey of the Second Geological District, including Essex county. This report, however, contains almost nothing on the geology of the Lake Placid region.

To Prof. J. F. Kemp belongs the credit of first having done extensive field work which has resulted in solving many important problems in the geology of Essex county. He published reports, based upon reconnaissance field work, on the geology of the county in 1893 and 1895. These reports contain important data pertaining to the geology of that portion of the Lake Placid quadrangle which lies in Essex county. Based upon this reconnaissance work, Professor Kemp also published a report, accompanied by a geologic map, on the vicinity of Lake Placid. At one time it was planned that Professor Kemp and the writer should prepare a joint report and map based upon a detailed study of the Lake Placid quadrangle. Soon after entering the field in 1915, however, Professor Kemp was obliged, on account of health, to abandon the work. He generously allowed the use of certain data on his field map. The writer gratefully acknowledges his indebtedness to Professor Kemp.

Prof. H. P. Cushing, in his Preliminary Report on the Geology of Franklin County, makes a number of references to the rock formations in the vicinity of Franklin Falls, in the northwestern part of the quadrangle. Professor Cushing also briefly refers to some of the formations in that part of the quadrangle which lies in Clinton county in his Report on the Geology of Clinton County.

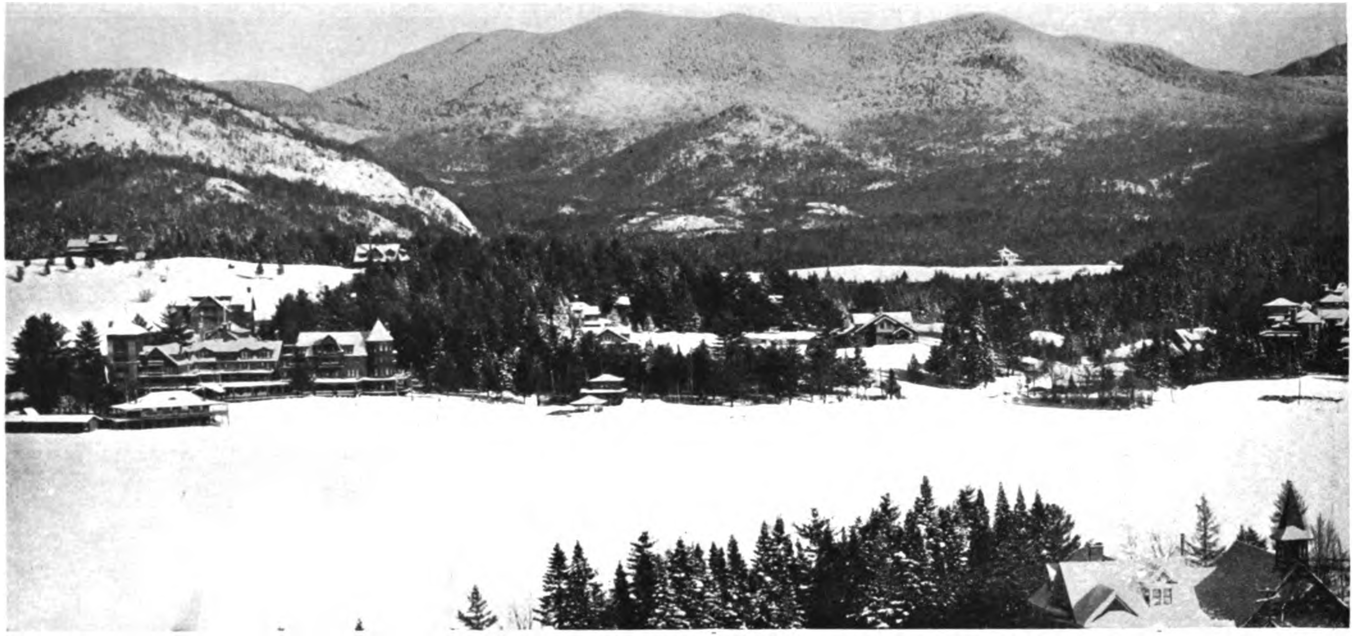
Mr H. L. Alling, who contributes the chapter on the Pleistocene of the quadrangle in this bulletin, has kindly furnished data, more especially the location of several diabase dikes and Grenville limestone outcrops, and the use of some thin sections of rocks.

Mr Herbert Insley, a former student in the writer's classes, assisted in the survey around Keene and on the rough Sentinel range. For this service the writer is sincerely grateful.

Prof. D. W. Johnson has kindly permitted the use of two photographs.

Following are the principal publications which bear more or less upon the geology of the quadrangle:

Plate 1



I. L. Stedman, photo
Courtesy of Melvil Dewey

A winter view of the Sentinel range looking eastward from the Lake Placid Club grounds. Cobble hill on the left.

1842 **E. Emmons.** Survey of the Second Geological District (Adirondack mountains), pt 2 of The Geology of New York.

1895 **J. F. Kemp.** Preliminary Report on the Geology of Essex County. 13th Annual Rep't N. P. State Geologist, p. 431–72.

1895 **J. F. Kemp.** Preliminary Report on the Geology of Essex County. 15th Annual Rep't N. Y. State Geologist, p. 575–614.

1895 **H. P. Cushing.** Report on the Geology of Clinton County. 15th Annual Rep't N. P. State Geologist, p. 499–573, especially p. 543–44.

1898 **J. F. Kemp.** Geology of the Lake Placid Region. N. Y. State Mus. Bul. 21. p. 51–64.

1899 **H. P. Cushing.** Preliminary Report on the Geology of Franklin County. 18th Annual Rep't N. Y. State Geologist, p. 73–128.

1900 **J. F. Kemp.** Precambrian Sediments in the Adirondacks. Science, 12:81–98.

1905 **H. P. Cushing.** Geology of the Northern Adirondack Region. N. P. State Mus. Bul. 95, p. 271–453.

1914 **W. J. Miller.** The Geological History of New York State. N. Y. State Mus. Bul. 168, 130 pages, especially chapter 3.

1916 **W. J. Miller.** Origin of Foliation in the Precambrian Rocks of Northern New York. Jour. Geol., 24:587–619.

1917 **W. J. Miller.** The Adirondack Mountains. N. Y. State Mus. Bul. 193, 97 pages. A somewhat untechnical guide to the geology and physiography of the Adirondack mountain region.

1917 **N. L. Bowen.** The Problem of the Anorthosites. Jour. Geol., 25:209–43.

1918 **W. J. Miller.** Adirondack Anorthosite. Geol. Soc. Amer. Bul. 27:399–462.

Plate 2

Courtesy of the New York Central Lines

Mt Whiteface, looking northward from Lake Placid. The mountain rises more than 3000 feet above the surface of the lake. Sunrise notch and Sunrise mountain on the right.

GENERAL GEOGRAPHY AND GEOLOGY

The Lake Placid quadrangle lies immediately north of the great group of highest mountains in the Adirondack region. Altitudes range from 660 feet where the East Branch Ausable river leaves the quadrangle on the east, to 4872 feet at the summit of Mt Whiteface near the center of the quadrangle. Mt Whiteface rises majestically as a great mass culminating in a sharp peak from 2500 to 3800 feet above the immediately surrounding country. Around the nearly circular base of the mountain the distance is approximately 16 miles. Eight or ten sharp, rugged spurs with deep intervening valleys radiate from near the summit. The great bowllike depression just east of the summit of Whiteface was formerly occupied by a local glacier, and its remarkable shape is due to the action of the glacier in plucking out the rock. The valley between Esther mountain and Marble mountain was also formerly occupied by a local glacier.

Sentinel range, some 8 miles long, ~~has~~ several peaks rising from 3600 to 3902 feet above the level of the sea. This, too, is a very rugged, steep mountain mass. Just north of Sentinel peak is another fine example of a bowllike depression cut out by a local valley glacier. A local glacier also lay in the valley next to the north.

Pitch-off mountain, with altitude 3340 feet at the southern edge of the map area, is the northern slope of the still higher mountain within the Mount Marcy quadrangle.

St Armand mountain is an irregular mass with several points from 3100 to 3250 feet above sea level. It lies just northeast of Moose mountain, whose altitude is 3921 feet in the Saranac quadrangle.

Wilmington mountain is a relatively narrow ridge 7 miles long with a number of points 2800 to 3450 feet above sea level. It is a very rugged, densely wooded mountain rising 1500 feet above the narrow valley on the west and more than 2000 feet above the broad valley on the east.

Catamount mountain ridge, in the north-central portion of the map area, is about 3½ miles long and relatively broad with its summit (Catamount) 3168 feet above the sea. Its western end rises abruptly 1500 feet and, viewed from the broad valley on the west, it is a very impressive sight (see plate 19).

On a large scale, Mt Whiteface and Wilmington mountain taken

together, and, on a small scale, Catamount mountain, show a northeast-southwest trend which is common in the eastern half of the Adirondack region. The other mountains of the quadrangle are, however, very irregularly distributed.

There are three large, broad valleys. One of these with the villages of Wilmington, Haselton, and East Kilns in the northeastern part of the quadrangle, is approximately 10 miles long and from 2 to 4 miles wide, with altitudes from 660 to 1400 feet. This valley was once occupied by an extensive glacial lake (see chapter on the Pleistocene geology). A prominent valley, 7 miles long and 3 to 5 miles wide, lies in the northeastern part of the map area. Its altitudes vary from 1400 to 1700 feet, and most of it is the site of a former glacial lake. The third large valley lies in the southeast. It is 7 miles long and from 1½ to 3½ miles wide. Altitudes range from 1640 to 1900 feet. A former glacial lake also covered this area. Lake Placid now occupies the northern end of this valley.

Three large streams flow across the quadrangle, namely, Saranac river for about 8 miles across the northwestern corner, East Branch Ausable river for 9 miles across the southeastern portion, and West Branch Ausable river for about 20 miles from southwest to northeast almost across the middle of the map area. All the drainage of the quadrangle passes into these three rivers and northeastward into Lake Champlain. The West Branch Ausable river drains Lake Placid and, after pursuing a winding course for some miles through a broad valley in the vicinity of Newman, passes through a deep, narrow pass known as Wilmington notch, the rocky sides of which rise precipitously to a maximum height of 700 feet above the river on the east side, and 1700 feet on the west side (see plates 4 and 20). The explanation of this remarkable course may be found on a subsequent page. A mile beyond the Wilmington notch, the river descends more than 100 feet by waterfall (High fall, see plate 5) and cascades in a small gorge (see plates 13 and 14) cut in granite. Two miles beyond the High fall gorge the river flows through a narrow gorge known as The Flume (see plate 8), and then enters the broad valley in which are located the villages of Wilmington and Haselton.

There are twenty-four lakes and ponds within the quadrangle in addition to portions of two large reservoirs along the Saranac river.[1] Lake Placid, over 4 miles long and from 1 to 1½ miles

[1] These reservoirs are not shown on the accompanying geologic map, but they occupy the swamp areas above and below Franklin Falls.

Photo by I. L. Stedman, Lake Placid, N. Y.

Looking south across Lake Placid, from the summit of Eagle Eyrie.

wide, lies 1859 feet above sea level.[1] By many it is regarded as the gem of Adirondack lakes. Mt Whiteface rises majestically more than 3000 feet above the surface of the lake on the northeast, and Moose mountain rises over 2000 feet above the lake on the west. The lake contains two large, high rugged islands and one small one.

Morgan pond on Wilmington mountain has a remarkable situation at an altitude of 3020 feet.

The Lake Placid quadrangle contains a wonderful variety of rock formations, including most of the familiar Adirondack types as well as several others described in this bulletin for the first time. Excepting the Pleistocene deposits, all the rocks are of Precambrian age.

Oldest of all is the Grenville series which takes rank among the very oldest rock formations of the earth. It consists of gneisses, quartzites, and crystalline limestones. These are sedimentary rocks which have been thoroughly crystallized. There are no large areas, but many small masses are scattered throughout the quadrangle.

Next in age, definitely proved, is the Marcy type of anorthosite with its extensively developed facies known as the Whiteface anorthosite. These rocks, which are igneous in origin, are intrusive into, and therefore younger than, the Grenville rocks. Anorthosite is the most abundant rock of the quadrangle.

The syenite-granite series, with its several variations, is intrusive into both the Grenville and the anorthosite. It ranks next to the anorthosite in areal extent.

Of particular interest is a peculiar rock, called the Keene gneiss, occurring as a border zone between the anorthosite and the syenite-granite. There is strong evidence that this rock has resulted from the assimilation of anorthosite by the molten syenite or granite.

At several places in the northern portion of the quadrangle there are series of parallel, gneissoid, basic, usually badly weathered dikes cutting the granite. They are different from any rocks hitherto observed by the writer in the Adirondacks. It is probable that they are older than the gabbro below mentioned.

A number of gabbro bodies of the usual Adirondack kind occur within the quadrangle. These are seen to cut both the Grenville and the syenite-granite series.

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[1] The altitude number 1864 printed on the accompanying map was determined by an older survey.

Pegmatite dikes of wholly nonmetamorphosed material are occasionally present throughout the quadrangle.

Diabase, in the form of numerous nonmetamorphosed dikes, is the latest of the Precambrian rocks.

Paleozoic and Mesozoic rocks are entirely absent, but glacial deposits are widespread and varied, especially in the valleys.

Faulting appears to have played a much less important part than usual in the eastern Adirondacks, only a few fault zones having been observed, the principal one passing through the Wilmington notch.

THE PRECAMBRIAN ROCKS

Grenville Series

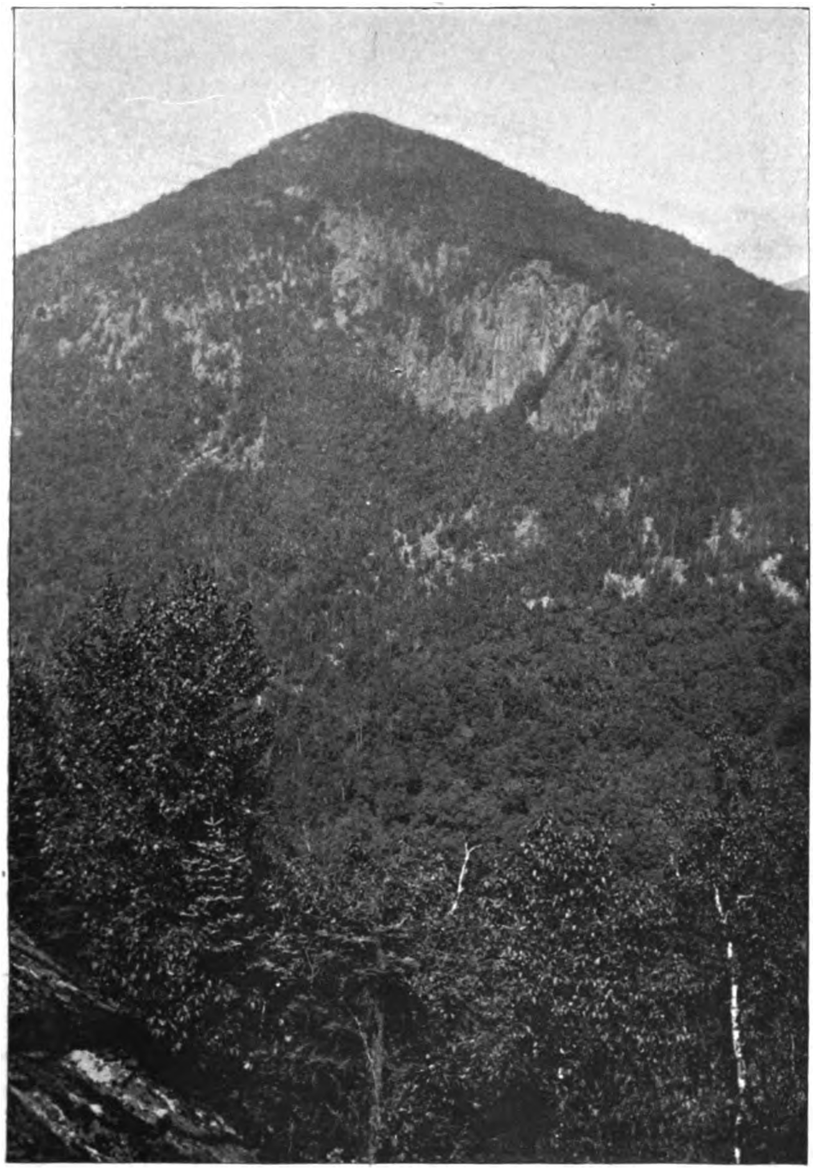
General statements. Among all the rocks of the quadrangle, those which comprise the Grenville[1] series are the most ancient. They rank among the very oldest known rocks of the earth's crust. It is certain that by far most of the Grenville rocks are of sedimentary origin, though all are now metamorphosed and thoroughly crystalline. In most cases the stratification surfaces are still plainly visible and these often separate rock layers of sharply varying composition. Various bedded gneisses, schists, quartzites and crystalline limestones almost, if not entirely, constitute the Grenville series, the original rocks having been shales, sandstones and limestones of the usual kinds. The presence of numerous flakes of graphite (so-called "black lead") scattered through many of the Grenville rocks also strongly indicates their sedimentary origin.

Grenville strata are common throughout the Adirondack mountain region and also in eastern Ontario. Their thickness is known to be very great — a few miles at the very least — with neither top nor bottom of the series definitely known. Since the Grenville strata throughout the Adirondacks have been all cut to pieces by vast intrusions of igneous rocks, their present distribution is very patchy, and the irregular scattering areas now visible are merely remnants of what was once a continuous body of strata covering not only all of northern New York, but also large adjacent areas, particularly eastern Ontario.

Within the Lake Placid quadrangle the Grenville strata are less abundant than usual throughout the Adirondacks. As shown on the accompanying geologic map, definitely known areas of Gren-

[1] This name has been given from the town of Grenville in the St Lawrence valley.

Plate 4



W. J. Miller, photo, 1916

Sunrise mountain with its precipitous eastern face rising 1700 feet above the river at the lower end of Wilmington notch. Viewed from the top of the gorge on the east side of the river. The rock is syenite.

ville, not one of them more than a few square miles in extent, are rather widely scattered over the quadrangle, but they make up only a small percentage of its area. They are mere fragments of the formerly continuous Grenville series which has been cut to pieces by vast intrusions of plutonic igneous rocks, especially the anorthosite and the syenite-granite series.

The actual extent of Grenville strata is somewhat greater than indicated directly as such on the geologic map. Thus, in the vicinity of Newman, the bedrock, probably mostly Grenville, is largely concealed under glacial deposits. Similar conditions probably also obtain in the areas of unknown bedrock west of the river between Keene and Upper Jay, and between Franklin Falls and West Kilns. Again, the areas of Grenville-anorthosite mixed gneisses, and of syenite or granite and Grenville mixed gneisses, contain much Grenville. Finally, there are occasional small unmappable masses of Grenville which occur as inclusions in the great intrusives. But, after making every reasonable allowance, it is believed that Grenville rocks do not actually occupy more than 8 or 10 per cent of the area of the quadrangle.

Compared with the Adirondacks in general, the Grenville rocks of the Lake Placid quadrangle are mostly of quite the usual sorts, namely, graphitic crystalline limestones, pyroxene gneisses, hornblende gneisses and quartzites.

Areas in the vicinity of Lake Placid. In the extreme southwestern corner of the quadrangle an area of about 1 square mile shows some good outcrops of Grenville. Dark hornblende-feldspar gneiss, hornblende-feldspar-garnet gneiss, together with some light-gray garnetiferous feldspar gneisses and a little quartzite, make up the main bulk of the rock. At one locality (near the diabase dike) the dark gneiss contains large red garnets with hornblende rims.

The area which extends from Pulpit mountain to Connery pond and southward several miles contains various Grenville rock types. The eastern portion of Pulpit mountain consists mostly of dark hornblende-feldspar-garnet gneiss with scattering red garnets up to 4 inches in diameter enveloped in rims of black hornblende. The hill south of Tom Peck pond contains mostly hornblende-feldspar gneisses (often garnetiferous) interbedded with considerable well-stratified pyroxene gneiss and a little biotite gneiss. On the ridge for 2 miles south from Big Cherrypatch pond the Grenville is mostly hornblende-feldspar gneiss, usually garnetiferous and with a little interbedded pyroxene gneiss. The southern

part of the area shows a number of exposures of dark hornblende-feldspar-garnet gneiss with red garnets up to one-half of an inch in diameter. A little quartzite was noted at one place.

About one-half of a mile east of the southern end of Mirror lake there is a large outcrop of dark, very gneissoid, but not banded, hornblende-feldspar-garnet gneiss with garnets up to an inch or more in diameter often inclosed in envelops of hornblende.

The small Grenville masses on and near Cobble hill, and 1 mile west of Coldspring pond, are hornblende gneisses, two of these masses being distinct inclusions in the syenite.

On the mountainside 1½ miles north of Eagle Eyrie (a few rods above the trail) there is an interesting exposure, several hundred feet long, of white, rather coarse-crystalline calcite marble with scattering small crystals of phlogopite, pyroxene and green apatite. On the east side it is in contact with syenite, while on the west it seems to overlie, in part at least, gray feldspar-quartz-garnet gneiss (presumably Grenville).

In the bed of a small brook one-half of a mile south of Owen pond there is a small exposure, clearly an inclusion, of Grenville limestone — some pure white and some rich in mica, pyroxene and pyrite — associated with Grenville gray feldspar-pyroxene gneiss.

Near Winch pond the inclusion of Grenville (see map) in the syenite is a light-gray feldspar-quartz gneiss.

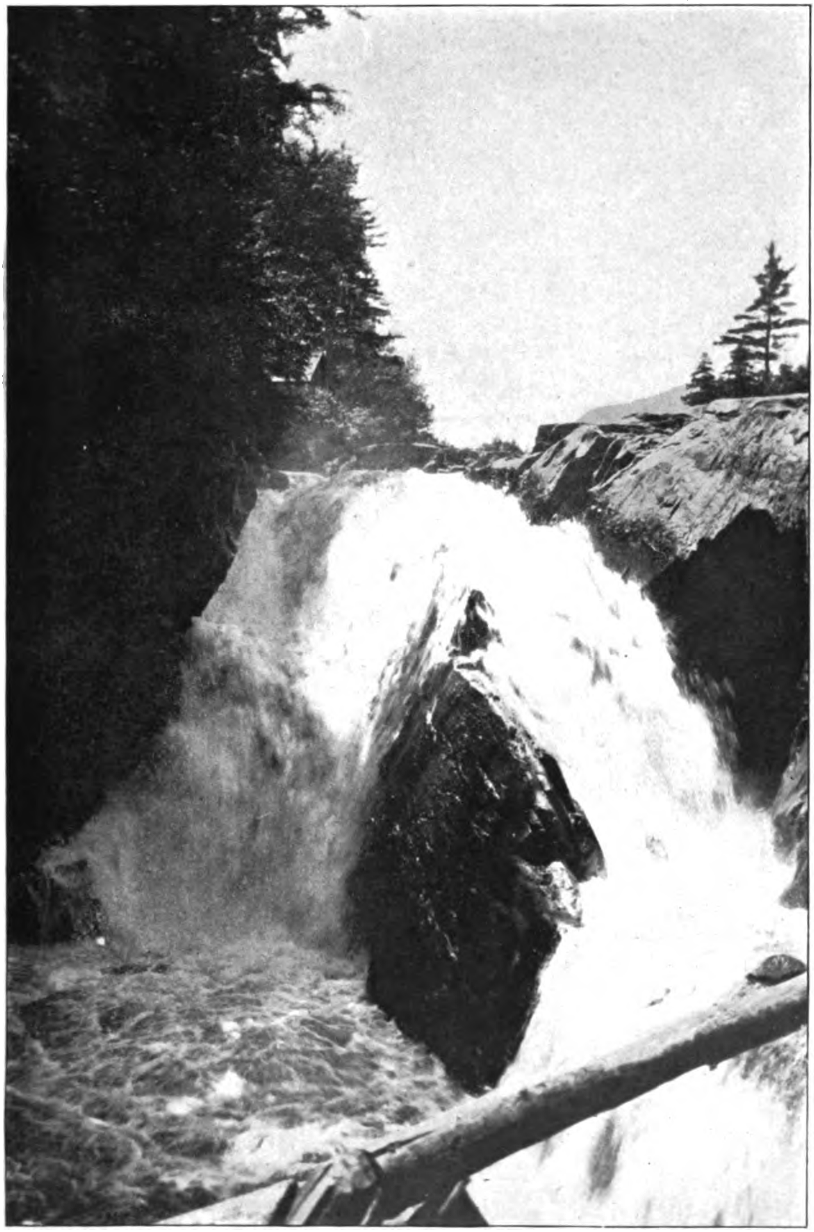
In the Wilmington notch a good exposure at the edge of the river (see map) shows well-bedded Grenville green pyroxene-feldspar gneiss and light-gray calcareous pyroxene-quartz gneiss, each about 20 feet thick.

The small area in Sunrise notch consists of quartzitic and pyroxenic gneisses.

Areas in the vicinity of Keene village. On the western side of the gorge of Ausable river (close to the map limits) there is an outcrop of Grenville limestone and close by it an outcrop of Grenville quartz-biotite gneiss or schist.

The Grenville which constitutes the hill from one-half to 1½ miles north of Keene is quite variable. At the south, hornblende-feldspar gneisses and quartzites are interbedded with some light-gray feldspar-graphite gneisses. The middle portion of the hill is mostly hornblende-feldspar gneiss. In the northern portion of the hill the rock is mostly green pyroxene-garnet gneiss with some interbedded hornblende gneiss and limestone, the limestone containing graphite and green pyroxene. The western of the two limestone outcrops shown on the map is the larger.

Plate 5



W. J. Miller, photo, 1916

High fall of the West branch, Ausable river

In the Grenville area about 1½ miles a little east of north of Keene, well-bedded quartzites and hornblende gneisses are prominently developed.

The area between 2 and 3 miles north of Keene shows a number of large exposures of typical hornblende-feldspar gneiss with one small limestone outcrop in the southeast.

On Styles brook, just above the falls, well-stratified Grenville hornblende gneiss and hornblende-garnet gneiss with some interbedded green pyroxene gneiss form the walls of a small gorge.

The Red Rock area shows very fine big exposures of variable well-stratified quartzite, some sharply defined beds being rich in green pyroxene, others in red garnets, and still others in phlogopite. Most of the rock contains flakes of graphite.

The small area 1½ miles northwest of Keene shows light-gray feldspar-mica-graphite gneiss. According to Kemp's 1898 map, limestone occurs here, but this was not seen by the writer.

The small Grenville areas east of Keene show green pyroxene gneiss and quartzite.

Area near Upper Jay. In this area, southwest of the village, the main body of Grenville appears to be dark hornblende-feldspar gneiss with quartzite or green pyroxene gneiss sometimes locally developed. Crystalline limestone and gneiss outcrop in the eastern corner of this area.

Wilmington mountain areas. In the area at the southern end of Wilmington mountain there are many fine big outcrops of well-stratified Grenville. The rocks are mostly green pyroxene-feldspar gneisses, biotite-feldspar gneisses, and some hornblende gneisses interbedded. In and about the graphite mines in the central-eastern part of the area there is considerable crystalline limestone associated with some pyroxene-garnet rocks.

The large West Kilns-Middle Kilns area shows a considerable number of good outcrops. On the side of Wilmington mountain the principal rocks are hornblende-feldspar gneisses and green pyroxene gneisses, both of these at times carrying garnets. Quartz-feldspar-mica gneiss and almost pure quartzite are there more locally developed. Within one-half of a mile east of West Kilns there are several ledges of clearly bedded quartz-feldspar-phlogopite-graphite gneisses, considerably weathered and rusty looking. Near the road three-fourths of a mile east of West Kilns, Grenville limestone and quartzite are poorly exposed, and one-fourth of a mile east of this, by the road, pyroxene-feldspar-quartz gneiss

outcrops. Parts of the latter rock are porous, probably due to weathering out of calcareous material. Just west of Middle Kilns, by the road, well-banded hornblende-feldspar gneiss shows in a good ledge. The Grenville at the base of Catamount mountain is mostly dark hornblende-feldspar gneiss, often garnetiferous. In the quarry (see map) in this area there is a fine big exposure of very coarse crystalline limestone with some portions containing large irregular masses of clear quartz and one-fourth to one-half inch crystals of dark-green pyroxene and pale bluish green apatite. Other portions of this limestone contain considerable titanite.

Areas near Franklin Falls. The Grenville area east and north of Franklin Falls shows very fine outcrops. By the roadside, one-third of a mile north of the village, there is a large exposure of distinctly bedded, impure, badly weathered limestone containing quartz, graphite and pale-green pyroxene. It is associated with some hornblende-feldspar gneiss and calcareous quartzite with flakes of graphite and phlogopite and specks of pyrrhotite. On the road just east of Franklin Falls there are good ledges of greenish gray quartz-pyroxene gneiss, some of which contain graphite. Steep ledges forming the north bank of the river just opposite are of similar rock. On the road one-half of a mile east of the village there are small exposures of rotten graphitic limestone and quartzitic gneiss with graphite. The southern part of the area consists of hornblende gneiss and quartzite interbedded.

The small area 1½ miles east of Franklin Falls shows greenish gray quartz-pyroxene gneiss not certainly in situ.

At Woodruff fall coarse crystalline limestone containing graphite and green pyroxene shows in an old quarry. A few rods to the south there are ledges of hornblende-feldspar gneiss. The other two limestone outcrops indicated on the map are associated with pyroxene gneiss.

In an old prospect hole, one-half of a mile south of Franklin Falls, coarse crystalline limestone with much graphite is exposed.

The small area 1 mile east of Franklin Falls shows hornblende gneiss and quartz-pyroxene gneiss interbedded.

Anorthosite Series

General statements. So far as now known, the anorthosite was the first of the great intrusive bodies which broke through the Grenville strata. This rock is almost wholly confined to an area of about 1200 square miles mostly in Essex and Franklin counties.

It is prominently developed in the Lake Placid quadrangle. The typical rock, known as the Marcy anorthosite, is very coarse grained, bluish gray in color, and consists principally of basic plagioclase feldspar. A widely developed facies, known as the Whiteface anorthosite, is usually medium grained and characterized by a preponderance of milky white to light, greenish gray, basic plagioclase feldspar with small amounts of dark minerals. Both of the types locally contain considerable quantities of dark minerals. For most part the molten anorthosite appears to have pushed aside or displaced the Grenville rocks, though in many cases masses of Grenville, from small fragments to large bodies, were enveloped by the anorthosite, and in still other cases there appears to have been intimate injection of the Grenville by the molten anorthosite.

Marcy type of anorthosite. *Distribution.* This type of the anorthosite is named from Mt Marcy where the rock is so well developed. When the whole great body of Adirondack anorthosite is considered, this Marcy type is the most commonly and typically developed. Within the Lake Placid quadrangle, however, a special phase, known as the Whiteface anorthosite (see below) is actually somewhat more abundant in the known areas of outcrop.

The areas colored to show the extent of the Marcy anorthosite represent about 35 square miles wholly confined to the southern two-thirds of the quadrangle. There are ten areas in all. By far the largest exposed body of Marcy anorthosite in the quadrangle extends from the northern portion of the Sentinel range northeastward to the village of Haselton. Next to the largest body extends northwestward from Lake Placid for several miles. Two small bodies occur on the large islands in Lake Placid. Other small masses are located as follows: on Marble mountain; west of Wilmington village; and four small ones in the vicinity of Keene village. In addition to these definitely known areas, some Marcy anorthosite quite certainly lies concealed under Pleistocene deposits in the areas mapped as occupied by heavy glacial and postglacial deposits.

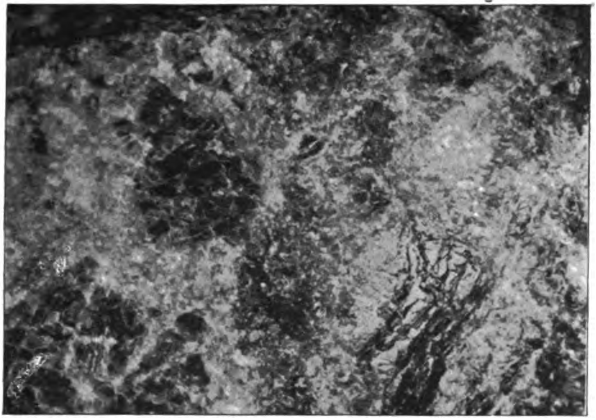
Megascopic features. The most common phase of Marcy anorthosite is a very coarse-grained, light to dark bluish gray rock consisting very largely of basic plagioclase feldspar, mainly labradorite. The dark bluish gray labradorite crystals usually vary in length from one-fourth of an inch to several inches, with crystals an inch long very common. Occasionally the labradorites exhibit the beautiful play of colors (chiefly green and blue) so characteristic

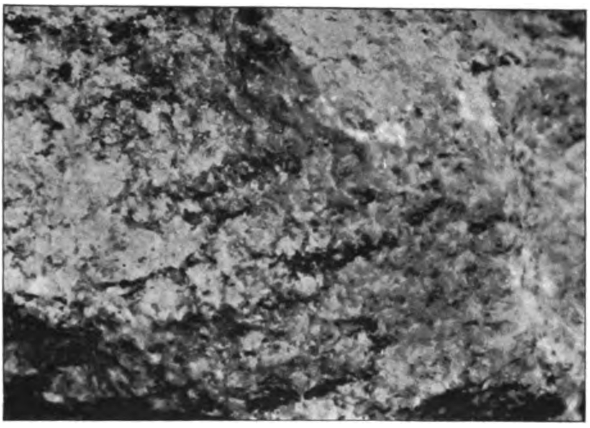
of this species of feldspar, but this phenomenon is neither so striking nor so common in the Marcy anorthosite as in labradorite from certain other regions. Twinning striations are usually evident on the shiny cleavage faces of the labradorite.

Accessory minerals visible to the naked eye are large individuals of pyroxene and hornblende, and small individuals of biotite, ilmenite, pyrite, garnet, and more rarely chalcopyrite and pyrrhotite. Due to decomposition of the dark minerals, the weathered anorthosite is usually light brown, but such rock is not common. Locally the amount of dark-colored minerals rises to 15 to 25 per cent when the rock should really be called anorthosite-gabbro. In many places such anorthosite-gabbro and typical anorthosite exhibit perfect gradations from one into the other, often within a few rods. The gabbroic facies is, however, decidedly subordinate in amount, and it has not seemed feasible to represent it separately on the geologic map.

An important facies of the Marcy anorthosite is one in which dark bluish gray labradorite individuals, from a few millimeters to an inch or more across, stand out conspicuously in a distinctly granulated groundmass of feldspar. In the fresh rock the granulated material varies from light gray to pale greenish gray. The granules usually vary in size from microscopic to 1 or 2 millimeters across. Even a glance at a hand specimen of such a rock makes it clear that the large labradorites are roughly rounded, uncrushed cores of what were considerably larger individuals before the rock was subjected to the process of granulation. In this type of rock, therefore, the labradorites stand out like phenocrysts, thus giving the rock a distinctly porphyritic appearance, though of course crystal boundaries are seldom if ever present. All degrees of granulation are shown, from rocks in which there is little or no evidence of crushing, to others in which relatively large, dark labradorites are scattered through a granulated groundmass, to extreme cases where the whole rock has been so thoroughly granulated that few, if any, labradorite cores remain. In spite of excessive granulation, the fresh rock is very firm and hard. The extremely granulated types, especially where somewhat weathered to light brown, bear a close resemblance to normal weathered syenite (see below) and may be readily mistaken for such in small outcrops in the woods. Careful examination of a number of specimens from an outcrop will, however, almost invariably yield at least a few small uncrushed cores of labradorite to furnish the clew to the nature of the rock. In connection with the granulation

Plate 6





W. J. Miller, photo

Upper figure. Photograph of a hand specimen of typical Marcy anorthosite. About natural size. Large dark patches are "augen" of labradorite whose natural color is very dark bluish gray. Matrix is mostly granulated plagioclase whose natural color is light greenish gray. A few of the small black patches represent chalcopyrite and pyrite whose natural colors are dark and light brass-yellow.

Lower figure. Photograph of a hand specimen of typical moderately gabbroid and gneissoid Whiteface anorthosite. About natural size, and almost natural color. White material is plagioclase, and dark material is mostly hornblende and pyroxene.

of this rock it is important to note that extreme degrees of crushing may often be observed in single outcrops of ordinary dimensions. A striking example of such phenomena is in the big ledge on the shore of Lake Placid at the southwestern end of Moose island where coarse-grained, nongneissoid anorthosite, with labradorite crystals up to 4 inches across, has in it a zone of much finer grained and moderately gneissoid anorthosite, the one grading into the other. Another illustration is in the road metal quarry near the road 1½

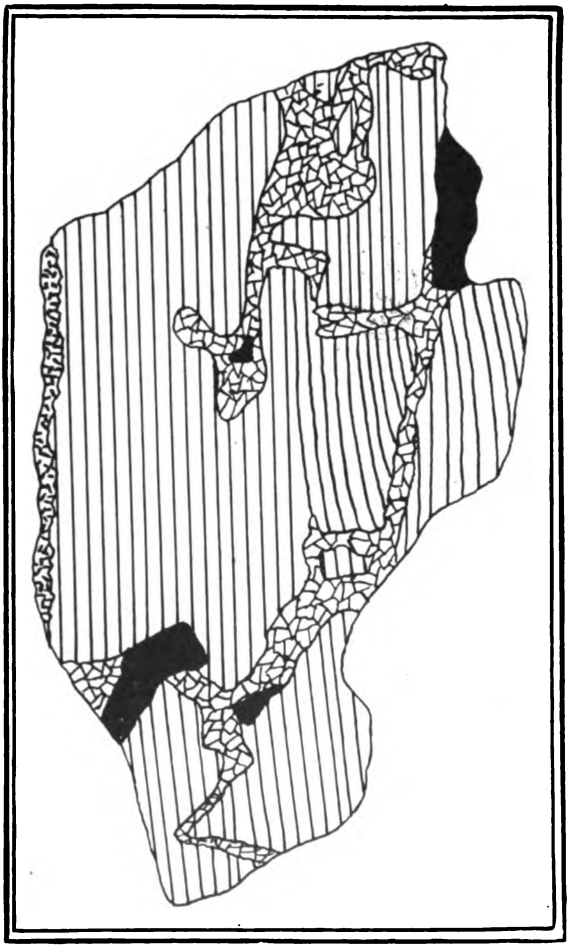


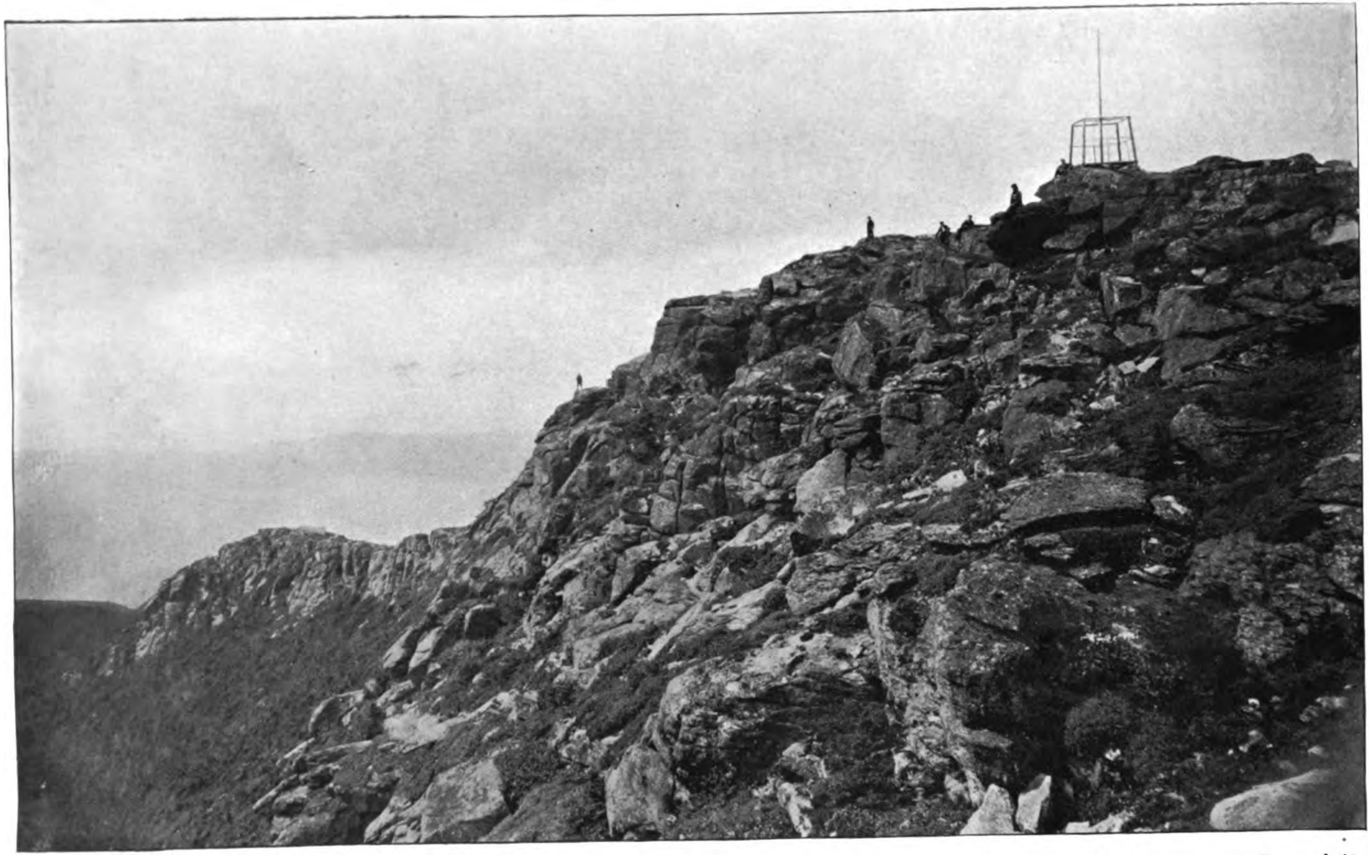
Fig. 1 Sketch of a large crystal of labradorite from the anorthosite quarry 1½ miles northeast of Upper Jay. Natural size. Note the large amount of granulated feldspar irregularly distributed through the crystal. Due to deformation during the process of granulation, the twinning bands are distinctly curved in the middle right portion and sharply shifted in position in the lower portion. Dark patches are pyroxene. Dotted rim on left is granulated garnet.

miles northeast of Upper Jay where is to be found one type of anorthosite made up of crystals of labradorite from one to several inches across with evidence of only moderate crushing, along with another type in which only occasional large rounded cores are left, and still other types in which practically all the feldspar has been granulated into a fine to medium-grained rock. These types are in zones which show perfect gradations from one extreme to the other.

Most of the typical Marcy anorthosite is practically devoid of foliation, hence the general absence of dip and strike signs from these areas on the geologic map. In some places, where the rock is only moderately coarse grained, there is a noticeable tendency for the feldspars to show a crude parallelism. It is usually impossible to determine satisfactorily the dip and strike of such foliation in ordinary outcrops in the woods. The more gabbroic phases of the rock do, however, often exhibit a fair to well-defined foliation due to the parallel arrangement of the dark-colored minerals. An important consideration is the frequent gradation from well-foliated to slightly or nonfoliated anorthosites or anorthosite-gabbros within short distances, often not more than a few rods. The causes of the foliation and granulation of the anorthosite are evidently closely related and this matter is considered below in the chapter on Structural Geology.

Microscopic features. In accompanying table 1, the six thin sections were selected to illustrate the usual mineralogical variations of the Marcy anorthosite. About a dozen mineral species in all were noted. By far most of the feldspar is seen, under the microscope, to be striated labradorite, to possibly bytownite in some cases. Where more acidic plagioclase is present, it is always in subordinate amount. In thin section, with a low power of the microscope, the larger labradorites are usually seen to be more or less filled with very dark dustlike particles. With a higher power these are seen to be practically opaque, slender prismatic, or sometimes tabular, forms with parallel arrangement often strung out parallel to the twinning bands of the feldspar. Professors Cushing and Kemp, who have noted such inclusions, think they are most likely ilmenite. They no doubt give the dark color to the labradorite. Monoclinic greenish gray pyroxene with good cleavage — usually augite but sometimes diallage — appears in all the slides. The chlorite in slide 5 was quite certainly derived from pyroxene. The hornblende exhibits good cleavages and pleochroism from

Plate 7



I. L. Stedman, photo
Courtesy of Melvil Dewey

The great ledge of Whiteface anorthosite which forms the southern face of the top of Mt Whiteface.

Table 1 Thin sections of anorthosite

	Slide no.	Field no.	Labradorite	Oligoclase to labradorite	Hornblende	Monoclinic pyroxene	Diallage	Hypersthene	Biotite	Garnet	Magnetite or ilmenite	Chalcopyrite, pyrrhotite or pyrite	Apatite	Chlorite	Zircon	Titanite	Hematite	Muscovite	Quartz	Calcite
Marcy anorthosite	1	5g3	99			little					¼		¼	½						
	2	6b1	82		2	8			½	7	¼	little								
	4	6b1	93		2		3		½	1	½	little			little					
	5	7c1	95																	
	35	7c3		95	1	1			½	½	¼	little	little	1½						
	44	8a3		98	¼	½					¼			1						
Whiteface anorthosite	6	1k2		93						1		little	little	5	little	little		½		
	6a	1k2		93	5	½			1		½		little		little					
	7	6e1		86	6	2			2¼	little	½		3							
	8	4d1		90	3	6					½				little	½				
	9	5g1		97	1	1½							little		¼		¼			
	13	9f3	98		1	½					¼		¼							
	14	8f4	88		4¼	7				¼		little	little		little					
	15	8i1	92		2	5					¼		¼						½	
	17	9i1	86		3	8	3					little								
	18	9g13		75		25					little					little				
	19	1L8	95			4½					¼					¼				
	20	7f7b	94		2	3				½	½		little							
	34	6e1		50	3	10		30		1½	3	little	2		little					½

No. 1, five-sixths of a mile east-southeast of Owen pond; no. 2, southwestern end of Moose island in Lake Placid; no. 4, same; no. 5, Undercliff, on Lake Placid; no. 35, three-fifths of a mile north of Undercliff; no. 44, five-sixths of a mile north of Loch Bonnie; nos. 6 and 6a, river gorge one-half of a mile south of Keene; no. 7, by the river two-thirds of a mile southwest of Copperas pond; no. 8, one-half of a mile northwest of Malcom pond; no. 9, one-half of a mile east of Owen pond; no. 13, one-third of a mile northwest of the summit of Mt Whiteface; no. 14, summit of Mt Whiteface; no. 15, just above bridge at The Flume; no. 17, The Flume; no. 18, between the tongues of granite 1⅛ miles northeast of the summit of Little Whiteface mountain; no. 19, by the road three-fourths of a mile east-northeast of Keene; no. 20, two-thirds of a mile northeast of the summit of Sunrise mountain; no. 34, same locality as no. 7 above.

yellowish green to deep green. Garnet is quite certainly of secondary origin, having developed along the contact between feldspar and pyroxene, or as rims around the pyroxene. The other minerals require no special comment. Under the microscope, the granulation is often a striking feature.

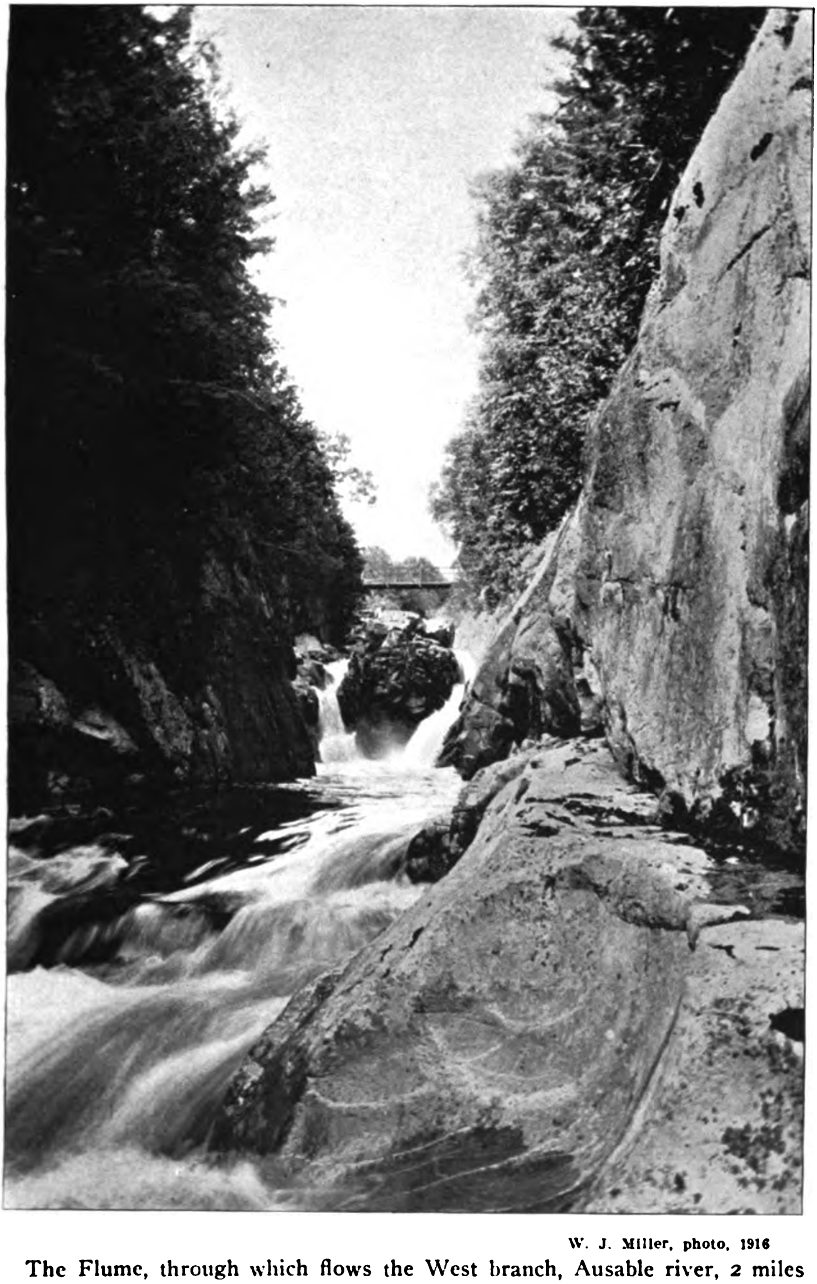
Whiteface type of anorthosite. *Distribution.* Of the definitely known areas of outcrop of anorthosite within the quadrangle, the Whiteface type, where practically free from mixture with other rocks, occupies about 40 square miles. It is, therefore, somewhat more extensive than the Marcy anorthosite. There must be added some 2 or 3 square miles of Whiteface anorthosite more or less intimately mixed with other rocks and mapped as such. An unknown, though considerable, amount of this anorthosite also

extends under cover of glacial drift where such deposits effectually conceal the underlying rocks, this being particularly true east and southeast of Franklin Falls, west and north of Wilmington, and north of Clifford Falls. So far as known at present, this Whiteface type of anorthosite appears to be relatively more abundant in the Lake Placid quadrangle than in any other portion of the Adirondacks. Professor Kemp has described similar rocks as occurring in smaller amount in the Elizabethtown quadrangle.

The Whiteface anorthosite is most irregularly distributed with reference to the other rocks. One reason for this is that the later syenite-granite intruded it so very irregularly. Although the Whiteface anorthosite is quite certainly a differentiation phase of the Marcy anorthosite, and, in a broad sense, may be regarded as a border facies of that rock, nevertheless it does not form well-defined borders about the Marcy anorthosite as the gabbroic facies do about the anorthosite of the Long Lake and Elizabethtown quadrangles mapped by Professors Cushing and Kemp respectively. The largest area of Marcy anorthosite is, to a considerable extent at least, flanked on either side by Whiteface anorthosite. On the north, however, the Whiteface rock is more extensively developed than the Marcy rock. Also, some small mappable bodies of both Whiteface and Marcy anorthosite are isolated from the larger bodies. It is by no means uncommon to find within the areas of Marcy anorthosite small local developments of rocks which greatly resemble the Whiteface type and vice versa. In short, the differentiation of the anorthosite magma was asymmetric and this, combined with the very irregular intrusion of the later syenite-granite body, accounts for the very uneven distribution of the anorthosite.

By far the largest area occupies much of Wilmington, Whiteface and Esther mountains, Knapp hill and vicinity, and the vicinity of Franklin Falls. An area several miles long mostly occupies the valley of the West Branch Ausable river from The Flume to near Connery pond. Several square miles of the Whiteface anorthosite occur in the vicinity of Keene, and a little over 1 square mile in the vicinity of Upper Jay. Areas of less than 1 square mile are located as follows: the southern base of Catamount mountain; 1 mile north of Middle Kilns; 1¼ miles northeast of Wilmington; southern slope of Little Whiteface mountain; on Hawk island, and on a portion of Moose island in Lake Placid; along the river west of Malcom pond; 2½ miles northeast of Keene; one-half of a mile south of Keene; and 1½ miles southwest of Upper Jay.

Plate 8



W. J. Miller, photo, 1916

The Flume, through which flows the West branch, Ausable river, 2 miles southwest of Wilmington. The rock is pinkish gray Whiteface anorthosite.

Megascopic features. A glance at 35 or 40 specimens of Whiteface anorthosite shows the usual rock to be medium grained and white, light gray, pale greenish gray, or, more rarely, pinkish gray, depending upon the color of the plagioclase feldspar. In most cases the greenish tint seems to be due to stains of chlorite or serpentine which have resulted from the decomposition of the dark minerals. A few specimens contain no large uncrushed cores of labradorite, but the outcrops from which such specimens come show these large labradorites to be sporadically present. Nearly all the specimens contain from 1 to 10 or 12 per cent of dark minerals, these being principally pyroxene and hornblende, with garnet and biotite less common, and tiny grains of oxides and sulphides of iron in most specimens.

A gneissoid structure is generally well enough developed to be readily noticeable in the hand specimens, this being particularly true of the rocks relatively richer in dark minerals. Many of the rocks show more or less evidence of granulation, sometimes to an excessive degree, but many others appear not to have been noticeably granulated.

The most typical Whiteface anorthosite, so well exposed at the top of Mt Whiteface, is medium grained, and consists of white plagioclase (all or nearly all labradorite) with 5 to 12 per cent of dark minerals scattered through the mass parallel to a crude foliated structure. Such a rock stands out in marked contrast against the most typical Marcy anorthosite which has nearly the same composition, but which is very coarse grained, light to dark bluish gray, and rarely foliated. Since both types are differentiates of the same cooling magma, they are not sharply separated, and it is often difficult in the field to draw other than arbitrary lines between them. This matter is more fully discussed below.

Local variations of the more typical Whiteface anorthosite are richer in dark minerals, which may make up from 15 to 30 per cent of the rock. In short, they are nearly always clearly foliated gabbroic anorthosites with white or light-gray feldspar. Such rocks are not abundant and they do not exist as rather definite borders about the anorthosite like the gabbroic border phase of anorthosite in the Long Lake quadrangle, as described by Cushing. Rather, these gabbroic phases occur very locally as zones or belts here and there throughout the areas of Whiteface anorthosite. So far as could be made out, they are not different from the typical Whiteface rock except for the higher content of dark

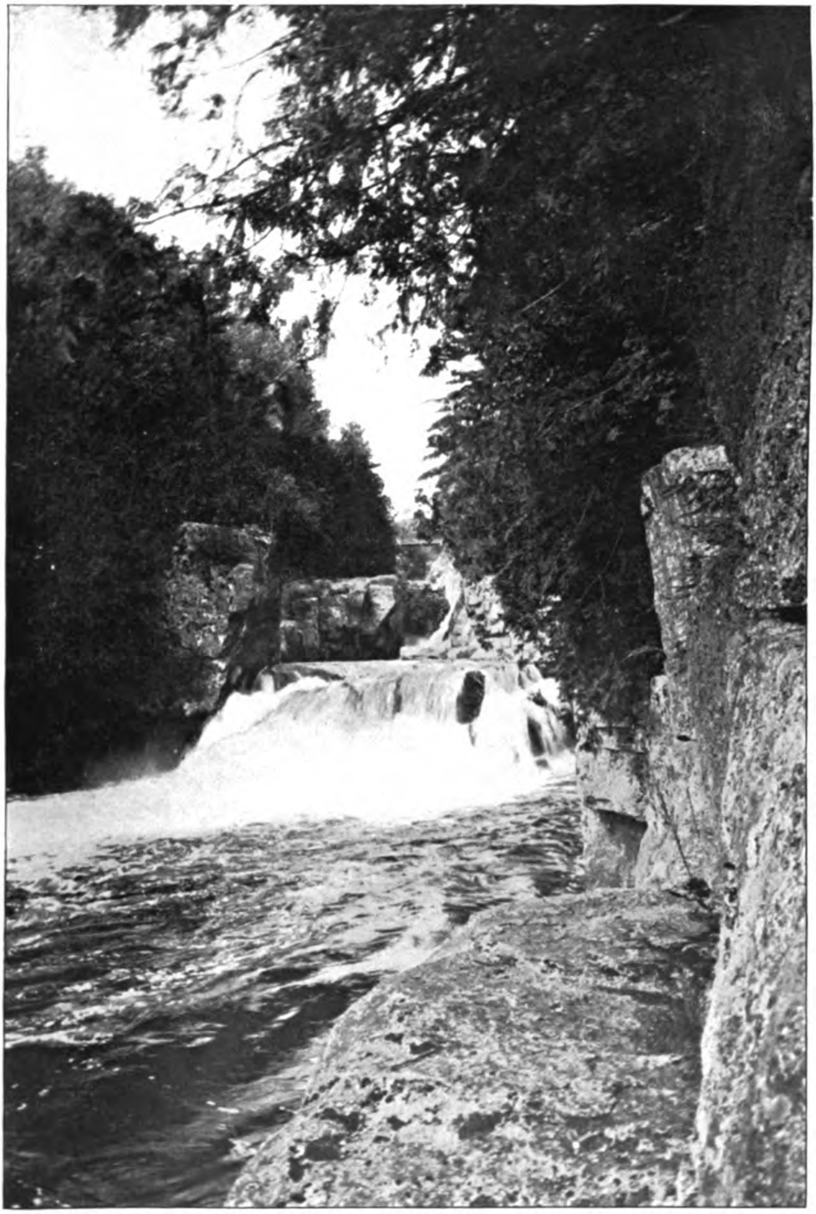
minerals, including garnet. A few examples follow. On the southern side of Hawk island in Lake Placid, big ledges show typical nearly white anorthosite and a gray anorthosite with 20 to 25 per cent of dark minerals, these two facies not being sharply separated. Along the river two-thirds of a mile west-northwest of Owen pond there are big ledges of Whiteface anorthosite with zones of very gneissoid, dark, gabbroic anorthosite. On the mountain spur two-thirds of a mile southeast of Morgan pond there is locally developed in the Whiteface anorthosite a strongly gneissoid facies. In the little area of mixed gneisses one-half of a mile east of Keene village the Whiteface anorthosite shows a local development rich in black minerals and garnet. By the river three-fifths of a mile west of Owen pond a single outcrop exhibits quite typical Whiteface anorthosite and a very gabbroic facies (no. 34 of table 1) in fairly sharp contact but without one cutting the other. Local variations of the sort here described are believed to have been produced as a result of differential flowage under moderate pressure in the cooling and differentiating anorthosite magma, this matter being rather fully considered beyond.

Certain exceptional types of very limited extent deserve mention. One of these forms the walls of The Flume through which flows the West Branch Ausable river. It is medium to moderately coarse grained, consists very largely of pink labradorite together with 2 to 15 per cent of hornblende and pyroxene scattered through the mass, and is at times slightly gneissoid. This is no. 17 of table 1. It contains no large blue labradorite crystals. Some small drawnout or lenslike inclusions of Grenville pyroxene gneiss occur, a careful study of these in the field having led to the suggestion that most of the much smaller (one-fourth to one-half of an inch) lenslike masses which make up 5 to 15 per cent of considerable portions of the rock are really very small fragments of Grenville gneiss which were caught up in the intruding magma and roughly arranged parallel to the magmatic lines of flowage.

The only other similar pink anorthosite found, occurs in the small area on the mountain side 1 mile east-southeast of Owen pond. This rock never shows over 2 per cent of dark minerals, and it contains no inclusions of Grenville.

Another exceptional type is medium grained and almost pure white, with about 1 per cent of green pyroxene and very few scattering grains of ilmenite and titanite. In thin section it shows fully 24 per cent of colorless monoclinic pyroxene with good cleavages. This is no. 18 of table 1. It is finely exposed in bare

Plate 9



W. J Miller, photo, 1916

Lower end of The Flume, 2 miles southwest of Wilmington.

ledges on top of the mountain spur 1⅓ miles northeast of the summit of Little Whiteface mountain.

Microscopic features. The thirteen thin sections listed in table 1 are from specimens chosen to illustrate the usual range in mineral composition of the Whiteface anorthosite of the quadrangle. Altogether some sixteen or seventeen mineral species were noted. Plagioclase feldspar, chiefly labradorite, always makes up the main bulk of the rock, being seldom less than 85 per cent. Oligoclase and andesine commonly occur in small amounts. So far as observed, the feldspar never shows the black dustlike inclusions so common in the labradorite of the Marcy anorthosite. Some of the large phenocrysts probably would show them, but none of these appear in the thin sections examined.

Greenish gray, or less commonly a nearly colorless, monoclinic pyroxene (in one case some diallage) appears in all the sections except no. 6, in which slide the chlorite was evidently largely derived from pyroxene. In no. 18 all but 1 per cent of the pyroxene is nearly colorless and the large amount is very exceptional. Pyroxene is the second most abundant constituent of the rock.

Next in amount comes the hornblende, never more than 5 or 6 per cent. Its pleochroism is usually greenish yellow to deep green or brownish green, and the cleavages are good.

Biotite was noted in only one slide, but it was occasionally noted in the field. Red garnet occurs in several slides, but it is present as scattering grains through the Whiteface anorthosite in many localities. Ilmenite (or magnetite) is generally present in tiny grains. Tiny prisms or rounded grains of apatite, zircon or titanite often occur in very slight amounts. Hematite, muscovite and quartz (probably secondary) are rare.

So far as can be judged by a study of hand specimens and thin sections, it seems to be quite the rule that the Whiteface anorthosite is less granulated than the Marcy anorthosite. Only exceptionally does the Whiteface type appear to have been severely crushed. A possible explanation will be offered beyond under the caption "Foliation."

Chemical composition of the anorthosite. Analyses of the Marcy type of anorthosite from the summit of Mt Marcy, and of the Whiteface type from the summit of Mt Whiteface, have been made for, and described by, Professor Kemp.[1] They are as follows:

[1] N. Y. State Mus. Bul. 138, p. 32–34 and 36–37. 1910.

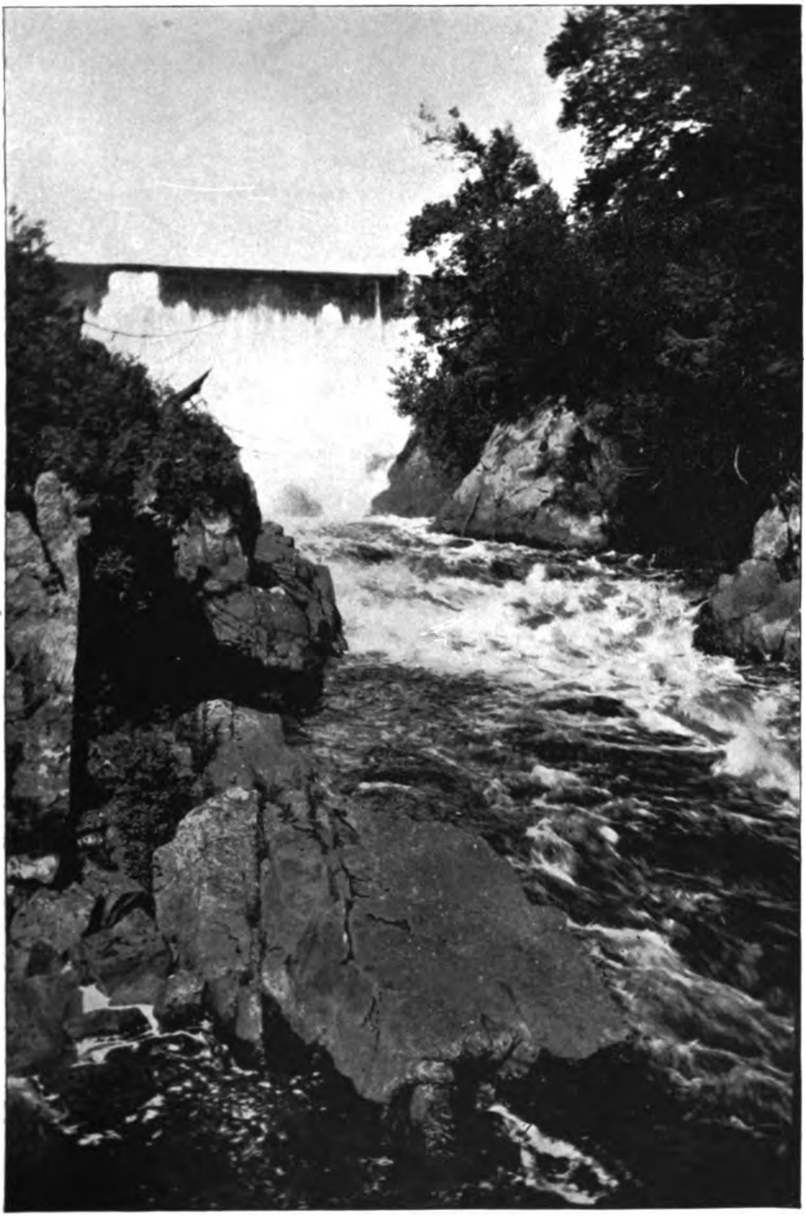
	1	2
SiO_2	54.47	53.18
Al_2O_3	26.45	23.25
Fe_2O_3	1.30	1.53
FeO	.67	1.82
MgO	.69	2.60
CaO	10.80	11.18
Na_2O	4.37	3.97
K_2O	.92	.86
H_2O+	.53	1.13
CO_2		.34
TiO_2		.45
S		tr.
P_2O_5		.09
MnO		.11

No. 1 represents the analysis by A. R. Leeds of the rock from Mt Marcy, and no. 2 represents the analysis by George Steiger of the rock from Mt Whiteface. According to Kemp, no. 1, in the Quantitative Classification of Cross Iddings, Pirsson, and Washington, belongs in class 1 (Persalane), order 5 (Canadare), rang 4 (Labradorase), subrang 3 (Labradorose); and no. 2 falls in class 2 (Dosalane), order 5 (Germanare), rang 4 (Hessase), subrang 3 (Hessose). The mineral composition of a thin section of rock from the summit of Mt Whiteface is shown by no. 14 of table 1 on page 21. These two analyses are doubtless very representative of the more common Marcy and Whiteface types of anorthosites in the Lake Placid quadrangle, as judged by the microscopic examination of various thin sections. The analyses show a close similarity in the chemical composition of these two rock types. Order, rang and subrang are the same for both, the difference in class no doubt being due to the somewhat greater percentage of ferro-magnesian minerals in the Whiteface rock which happened to be chosen for analysis. Such close similarity of chemical composition strongly supports the idea that the Marcy and Whiteface types of anorthosite represent differentiates of the same magma.

The rather high percentage of potash in rocks of this character calls for explanation. The lack of such dark-colored minerals as would furnish enough potash causes Kemp[1] to think that orthoclase

[1] N. Y. State Mus. Bul. 138, p. 30. 1910.

Plate 10



W. J. Miller, photo, 1916

Gorge and falls (over dam) of Saranac river at Franklin Falls. The rock is Whiteface anorthosite.

must be present up to 5 per cent or more as untwinned feldspar. Cushing, however, says: "The potash is in the labradorite (or other plagioclase), replacing a certain amount of soda" and "that analyses of this feldspar always show it." If orthoclase is present in the typical anorthosites, the writer has been unable to demonstrate it in the thin sections examined. Usually the plagioclase is beautifully and completely twinned, but many of them are much less so, some of the slices showing only a little very local, very faint twinning. Still other feldspar slices, which show no twinning but which have apparently similar index of refraction and double refraction, are quite certainly untwinned plagioclase. It seems most probable, therefore, that much, if not all, of the potash is in the plagioclase, with possibly a little in the dark minerals pyroxene and hornblende. Certain border phases of the anorthosite (below described) do contain orthoclase and microperthite, but these are believed to be due to mixing with the later syenite-granite magma.

Graphite in the anorthosite. Professor Kemp has in a letter furnished the following information regarding some interesting occurrences of graphite in the anorthosite. "Below the dam across the Saranac river at Franklin Falls, in the ledge on which it rests, there is a streak of graphite traceable for some yards. In several places on Knapp hill, 2 miles to the south, I found the graphite again in the Whiteface type. I have also found it in the Marcy type of anorthosite where exposed near the Grenville at the Red Rocks (near Keene). Probably the hydrocarbons which yielded the graphite were stewed out of the neighboring or included Grenville. This mineral is unusual in intrusive rocks."

The anorthosite an intrusive body. Until very recently, the Adirondack anorthosite has been regarded by the several workers in the region as an intrusive in the ordinary sense of that term. N. L. Bowen has, however, seriously questioned whether the anorthosite ever had been a truly molten mass. His reasons for thinking that it was never hot enough to have been really molten are based upon certain chemical considerations. His study of the literature led him to believe that his conception is not opposed by field facts. He stresses the simple mineral composition of the anorthosite and says in part: "Normally rocks are made up of several minerals, and when considering their magmas, we have to regard the various minerals as existing therein in mutual solution. . . . What, then, of the solution theory as applied to the anorthosites which typically consist almost exclusively of the single mineral plagioclase? Were they ever hot enough to be molten *per se?*

Chemical considerations and field facts both indicate that this latter question is probably to be answered in the negative. The chemical considerations bring out the improbability of the formation of anorthosite in any manner other than by the accumulation of plagioclase crystals precipitated from solution in a mixed magma." He therefore conceives of "the Adirondack anorthosite-syenite complex as essentially a stratified mass with syenite above and anorthosite below."[1]

Bowen's arguments from the theoretical standpoint, at least, are not to be lightly brushed aside. But after months of detailed field work in a region like the Lake Placid quadrangle where anorthosite is so prominently developed in all its phases, the writer believes that certain field facts are most decidedly opposed to Bowen's conception.[2] The main facts of this sort will be here briefly mentioned, actual examples and detailed descriptions being given elsewhere in this bulletin.

1 Sharply defined inclusions (small and large) of Grenville rocks occur in many portions of the anorthosite. These certainly bear every evidence of having been enveloped in an active magma. According to Bowen's hypothesis, how can such inclusions be accounted for?

2 In a number of places, clearly defined inclusions of anorthosite have been found in the syenite-granite series. Could fragments of the anorthosite, if formed by the settling of plagioclase crystals, have been forced upward by some process into the syenite-granite magma? Is it not much more plausible to regard these inclusions as indicating the envelopment of previously solidified anorthosite in an active syenite-granite magma?

3 Tongues or dikes of syenite and granite, as off-shoots of large masses of similar rocks, are known definitely to cut the anorthosite. Must we assume that tonguelike masses of overlying molten syenite or granite were forced downward into the anorthosite?

4 In a number of areas there is clear evidence that anorthosite has not only cut to pieces, but also intimately injected, Grenville gneiss. Could such injection gneisses have developed except by forcible and intimate intrusion of a highly molten mass into the Grenville?

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[1] These quotations are from an abstract of Bowen's paper in Bul. Geol. Soc. Amer. 28:154. 1917.

[2] The interested reader should consult Bowen's paper "The Problem of the Anorthosites" in Jour. Geol. 25:209–43, 1917, and the writer's paper "Adirondack Anorthosite" in Geol. Soc. Amer. Bul. 29:399–462, 1918.

5 Certain areas of mixed gneisses are anorthosite literally cut to pieces by syenite, often with fairly sharp contacts visible. Such a relationship is anything but stratiform as conceived by Bowen.

6 The anorthosite is by no means an almost perfect homogeneous mass of plagioclase. Most of the rock contains from 2 to 5 per cent of minerals other than plagioclase; portions with 5 to 10 per cent are not uncommon; and sometimes the rock contains 10 to 20 per cent, or even more, of dark minerals. Such gabbroic facies exist locally throughout the anorthosite body, sometimes as narrow zones or belts. On the basis of the origin of the anorthosite by the settling of plagioclase crystals, how are such variations to be accounted for? Also, since so much of the rock contains very appreciable amounts of ferro-magnesian minerals, is the mutual solution theory necessarily precluded?

7 Foliation, particularly of the Whiteface anorthosite, is by no means rare, and the writer has repeatedly seen highly gneissoid facies and facies with little or no foliation in close proximity. The writer believes that the alternations of gabbroic and nongabbroic facies, and gneissoid and nongneissoid facies, of the anorthosite are not results of regional compression, but that they were developed essentially by forced differential flowage in a congealing magma. This matter is explained at some length beyond under the caption "Foliation."

Some of the phenomena above described might possibly be harmonized with Bowen's hypothesis that the anorthosite originated by the "accumulation of plagioclase crystals precipitated from solution in a mixed magma," but, taken altogether, the writer believes that they render such an hypothesis untenable.

Relation of Whiteface anorthosite to Marcy anorthosite. As above stated, it is often a matter of judgment as to where the boundary lines between the Whiteface and Marcy anorthosites should be drawn. As a result of the field studies, the best evidence points to the conclusion that the two types are merely differentiates of the same cooling magma. On the one hand, in spite of many careful observations in the field in passing from one type across to the other, no evidence was obtained to show that one type cuts the other, while, on the other hand, one type of the rock grades into the other in many places. Transition rocks in some places form zones only some rods in width, while in other places they may be one-fourth of a mile across, and then any accurate delimitation of the Whiteface and Marcy types on the geologic map is impossible. Among many localities where intermediate facies are well

exhibited are one-fourth of a mile southeast of The Flume; on the mountain side one-fourth of a mile northwest of High fall; a long wide belt one-half to 1 mile west of Upper Jay; and along the northwestern base of the Sentinel range. In some places there are locally developed, without sharp boundaries, within the Marcy anorthosite masses of rock which are quite certainly to be classed with the Whiteface type and vice versa. Only two such masses are represented on the geologic map, one on the Mt Whiteface trail near Marble mountain, and the other on the mountainside 1¼ miles east-southeast of Owen pond.

As already shown, the Marcy and Whiteface types are very closely related in chemical composition, which strongly supports the view that the two are differentiates of the same magma. In the writer's paper[1] already referred to evidence is presented in support of the view that the whole body of Adirondack anorthosite is best to be regarded as a direct derivative of a laccolithic mass not much greater across than the area of its present outcrop; that the anorthosite differentiated practically *in situ* from an intruded gabbroid magma; that the anorthosite crystallized from the upper or residual portion of the magma during and after the sinking of many of the femic constituents; and that the Whiteface anorthosite developed both as an outer and an upper, somewhat more gabbroid, marginal facies of the anorthosite. Cushing[2] maintains that the gabbroid (Whiteface) facies developed as an *outer* chilled border of the anorthosite. His argument seems so conclusive that it is unnecessary to repeat it here. But, in this connection, it should be noted that the borders of the anorthosite body have in some districts, like the Lake Placid and the Schroon Lake quadrangles, been so cut out or cut to pieces by the later syenite-granite intrusions that the full original extent of the anorthosite is not now shown.

The writer believes further that the chilled gabbroid (Whiteface) border facies also developed as an *upper* limit which formerly existed as a cover resting directly on the whole great mass of anorthosite rather than merely as an *outer* limit, as Cushing suggests. Thus, the Whiteface anorthosite of the Lake Placid quadrangle does not exist merely as a definite fringe around the outer margin of the Marcy anorthosite. Typical Whiteface anorthosite occurs fully 14 or 15 miles within the present border of the anorthosite area, and inclusions in the syenite-granite series outside the general anorthosite area show that the Whiteface anorthosite formerly

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[1] Geol. Soc. Amer. Bul., 29:399–462.

[2] Jour. Geol., 1917, 25:506.

extended at least a few miles farther out than the present boundary. One area of Marcy anorthosite, 12 miles long within the Lake Placid quadrangle and extending an unknown distance into the Ausable quadrangle, is flanked on either side by Whiteface anorthosite. It is hard to resist the suggestion that the Whiteface rock formerly covered this whole mass of Marcy anorthosite. There is thus a distinct difficulty in the way of considering this Whiteface anorthosite merely an outer border facies. But if we do so regard this border facies, we are forced to conclude that it is exceedingly thick — that is to say, fully 10 or 12 miles — the width of the area containing Whiteface anorthosite representing practically the thickness of the border phase. This is scarcely possible. If, however, we consider the Whiteface anorthosite of the quadrangle to mark an upper limit of the great anorthosite body, but now partially removed by erosion and partly cut into by the syenite-granite series, not nearly so great thickness need be assumed. On this view a vertical thickness of fully 3000 feet is actually exposed in Mt Whiteface, and how much more should be added to make up for the upper portion removed by erosion is of course unknown. Probably little or none is to be added to the bottom, because Marcy anorthosite outcrops near the base of the mountain.

The anorthosite younger than the Grenville. There is twofold evidence that the anorthosite is younger than the Grenville series, namely, distinct inclusions of Grenville rocks in the anorthosite, and the more or less intimate penetration of the Grenville by the anorthosite, particularly by the Whiteface anorthosite.

Inclusions of Grenville in the Marcy anorthosite seem to be uncommon, having been noted in only one locality, namely, one-fourth to one-half of a mile north of Red rock in the vicinity of Keene, where a number of sharply defined, small inclusions of Grenville quartz-pyroxene gneiss and quartzite, and one 2-foot inclusion of limestone, are plainly imbedded in the typical Marcy anorthosite. The writer recalls having seen a 10-foot inclusion of limestone in anorthosite on the shore of Long lake in the Blue Mountain quadrangle (see Museum Bulletin 192).

In the Whiteface anorthosite, however, inclusions of Grenville occur in many places. Only a few of the better, more accessible localities will be cited. A 20-foot inclusion of nearly white Grenville quartz-feldspar-garnet gneiss clearly shows in a big ledge just east of Keene. Others, including quartzite and green pyroxene gneiss, occur for a mile eastward on the way up the hill east of Keene and along its summit.

In the quarry by the road 3 miles north of Keene, and also in ledges by or near the road one-half to two-thirds of a mile north of the quarry, the Whiteface anorthosite contains numerous bunches or lenses of Grenville, usually less than a foot long, as distinct inclusions.

Near the southeastern end of the Grenville area 2 miles due north of Keene, and also by the road in the mixed gneiss area 1½ miles southwest of Upper Jay, the anorthosite contains numerous sharply defined inclusions of Grenville gneiss and some of limestone. Most of these are less than 2 or 3 feet across.

In The Flume southwest of Wilmington, and also in the mixed gneiss area 2½ to 3½ miles west-northwest of Wilmington, portions of the anorthosite contain small lenses or irregular masses of Grenville green pyroxene gneiss.

Just west of the bridge at Franklin Falls the big ledges of Whiteface anorthosite contain a number of clearly defined bands or lenses of Grenville gneisses from a few inches wide and long, to 7 or 8 feet wide and 10 or 20 feet long (see plate 11). These inclusions are mostly gray quartz-feldspar-biotite gneiss, white feldspar-quartz-garnet gneiss, and quartzitic gneisses.

A big ledge of Grenville hornblende gneiss on the western shore of the river 1 mile south of Upper Jay is clearly intruded by a dike of Whiteface anorthosite 20 feet wide, this doubtless being an off-shoot from the anorthosite body just to the north.

In the areas of Grenville-anorthosite mixed gneisses, the Grenville rocks are literally cut to pieces by, and often injected with, much anorthosite, so that a separate mapping of the two formations is rendered impossible. Areas of this sort are considered below.

The above phenomena, mentioned somewhat in detail, strongly support the view that the anorthosite is, in the strict sense of the term, an intrusive body. Such evidence is directly opposed to the hypothesis of origin of the anorthosite as advocated by Bowen (see above).

The anorthosite older than the syenite-granite series. That the anorthosite is older than the syenite-granite series (described beyond) is conclusively proved both by tongues or dikes of syenite and granite cutting the anorthosite, and by inclusions of anorthosite in the syenite and granite. Several excellent examples of tongues of syenite and granite cutting anorthosite have been discovered by the writer within the quadrangle. These are of particular interest and importance because they constitute the only known evi-

Plate 11

W. J. Miller, photo, 1916

A ledge of Whiteface anorthosite by the road just across the river from Franklin Falls. The anorthosite contains a long, narrow inclusion of Grenville, gray, gneissoid feldspar-quartz-garnet gneiss. Width of the inclusion, 1½ to 2 feet.

dence of the sort in the northern portion of the great body of anorthosite demonstrating that the syenite-granite series is younger than the anorthosite. In fact the only other evidence of this kind thus far published is the important discovery by Professor Cushing of dikes of syenite cutting the western margin of the anorthosite in the Long Lake quadrangle.[1]

One mile south of Morgan pond, on a prominent spur of Wilmington mountain, two tongues or dikes of quartz syenite, clearly exposed for 50 or 60 feet, cut through a big bare ledge of Whiteface anorthosite (see map). The dikes are from 10 to 20 feet wide, and they are quite certainly off-shoots from the considerable body of quartz syenite which lies to the west. As would be expected in such narrow dikelike masses, the syenite is somewhat finer grained than usual, but otherwise it is quite normal. No. 39 of table 2 gives the mineral composition of a thin section from one of the dikes. The dike rock has weathered moderately to a light brown. It is very slightly gneissoid. The contacts against the anorthosite are not perfectly sharp and there may have been very slight assimilation along the borders.

Along the brook three-fourths of a mile west of The Flume, a tongue of quite normal quartz syenite 20 feet wide cuts typical Marcy anorthosite. This dike is an off-shoot from the considerable body of similar syenite extending southwestward (see map).

On the mountain spur 1¼ miles northeast of the summit of Little Whiteface mountain, a number of tongues of granite cut the Whiteface anorthosite. The relations are very clear in the big bare ledges. Of the three tongues of granite, shown on the map in somewhat exaggerated form, the middle one is only 20 feet wide, while the other two are some rods in width. The dike granite contains several per cent of hornblende, is clearly gneissoid, and weathers to pink or brown. South of the dikes just mentioned, several tongues of granitic syenite, none over 2 or 3 feet wide, cut the typical Whiteface anorthosite.

Inclusions of Whiteface anorthosite in syenite and granite, furnishing decisive evidence that the syenite-granite series is the younger, were observed at a number of localities. A few of these will be cited. Ledges of syenite by the river one-fourth of a mile east of High fall contain inclusions of Whiteface anorthosite arranged parallel to the foliation of the syenite. Near the base of Little High fall three-fourths of a mile northeast of High fall,

[1] N. Y. State Mus. Bul. 115, p. 479-82. 1907.

an 8-foot boulder of syenite has in it several distinct inclusions of Whiteface anorthosite, these usually not showing very sharp contacts against the syenite. On top of the hill in the area of syenite-granite and Grenville mixed gneisses, there are some small lenses of Whiteface anorthosite in the syenite parallel to its foliation. Near the middle of the northern boundary of the area of Keene gneiss 1½ miles west of East Kilns, a big ledge of typical syenite has many inclusions of Whiteface anorthosite which are bunches, lenses or bands from 2 or 3 inches to several yards long. Their borders are not always sharp against the syenite. This is one of the finest exhibitions of such phenomena observed by the writer within the quadrangle.

In the area of Whiteface anorthosite and syenite mixed gneisses from one-half to 2 miles east of High fall, the anorthosite has been much cut up by intrusions of syenite, good contacts having been noted at several places, but neither definite dikes of syenite nor inclusions of anorthosite were observed in this rough-wooded area.

The Syenite-granite Series

The syenite-granite series, prominently developed in the Lake Placid quadrangle, comprises a variable lot of rocks all of which, with one possible exception, are, apparently, facies of a single great cooling magma. Most common is a quartz syenite which grades into a basic (dioritic or gabbroic) facies on one side, and through granitic syenite to medium-grained granite or coarse-grained (usually porphyritic) granite on the other. Since such rocks, which are very abundant in the Adirondack region, have been described in detail in various State Museum bulletins and in other publications on Adirondack geology, no lengthy descriptions will be given in this bulletin.

That the syenite-granite series is younger than the anorthosite series has already been shown in the discussion of the anorthosite.

Quartz syenite. This is the most common and typical facies of the syenite-granite series. It is known to occupy approximately 35 square miles in very irregular areas mostly in the southern half of the quadrangle. In areal extent it is, therefore, about the same as the Marcy anorthosite but not so great as the Whiteface anorthosite.

As usual in the Adirondacks, this typical syenite is a medium-grained rock, dark greenish gray where fresh, and it weathers to a light brown. In some places a pinkish gray weathering was noted.

Outcrops seldom show a depth of weathering greater than a few inches. Immediate surfaces are sometimes light gray due to leaching out of the iron oxides by waters rich in decomposing organic matter.

The granularity varies considerably, in some places being rather fine grained, and in other places being slightly porphyritic. Granulation of the rock is often a notable feature, particularly when viewed in thin section under the microscope. The feldspars show the greatest effects of the crushing of the mineral grains. Notable differences in coarseness of grain or degree of granulation are sometimes very locally exhibited.

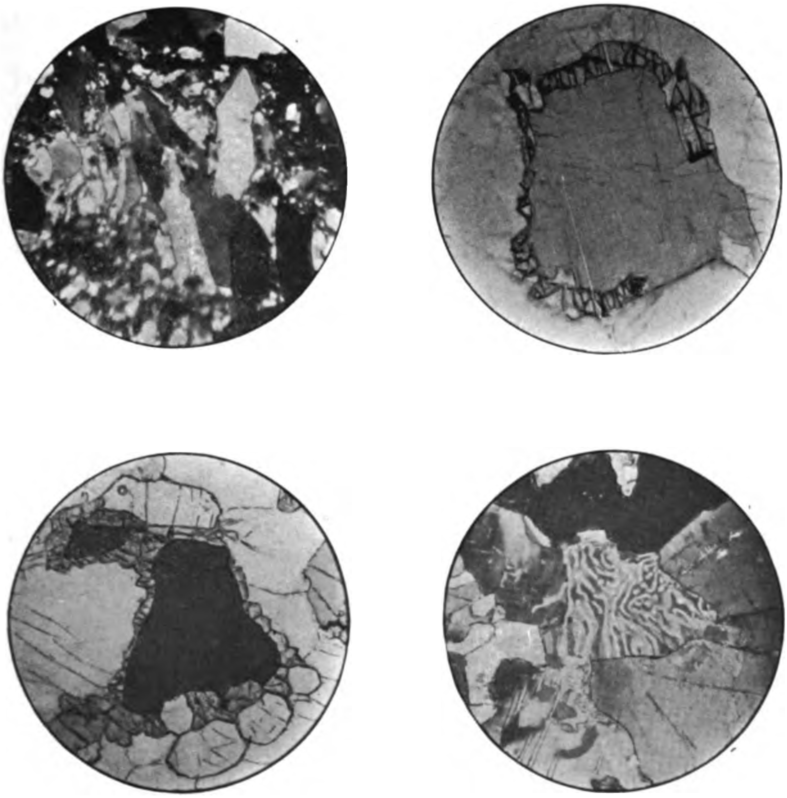
The degree of foliation of the syenite varies extremely. Very commonly the rock clearly displays a streaked or lenticular gneissoid structure which is accentuated by the arrangement of the dark minerals with their long axes parallel to the foliation as, for example, in the quarry at the extreme southern end of Lake Placid. In other places it is excessively gneissoid as near the road one-half of a mile north of Keene village, on the mountainside one-half of a mile southeast of the mouth of Styles brook, and on the mountain 1½ miles south-southeast of Upper Jay. Notable variations in degree of foliation are often very local, sometimes showing in single outcrops. The problem of the origin of the foliation is discussed beyond under the caption " Foliation."

The usual range in the mineralogical composition of the normal quartz syenite of the quadrangle is well shown in accompanying table 2. Microperthite is the most abundant constituent, and it occurs with orthoclase in about one-half of the slides examined. Oligoclase and quartz in moderate amounts never fail. Hornblende, pyroxene and garnet usually occur in small amounts. Some tiny grains or crystals of magnetite, apatite, and zircon almost invariably occur. A few other minerals are sporadically present.

Table 2 Thin sections of the syenite-granite series

	Slide no.	Field no.	Microperthite	Orthoclase	Oligoclase	Oligoclase to labradorite	Quartz	Monoclinic pyroxene	Diallage	Hypersthene	Biotite	Hornblende	Chlorite	Garnet	Magnetite	Pyrite	Apatite	Zircon	Titanite	Hematite	Calcite	Graphite
Normal quartz syenite	24	1k10	64	5	20	......	6	......	......	......	......	2½	......	......	2	......	little	little	......	......	......	....
	25	3c6	75	....	5	......	15	......	2	2	......	little	......	......	½	......	little	little	......	......	......	....
	27	4a1	72	....	8	......	10	......	4	4	......	½	......	½	little	......	½	little	......	......	......	....
	28	2 k 1	25	10	15	......	8	10	5	5	......	10	......	8	2	......	1	little	......	1	......	....
	29	1 k 12	60	10	5	......	5	......	5	4	......	3	......	6	1	little	½	little	......	......	......	....
	30	3 c 5	79	....	1	......	18	......	......	......	little	......	......	......	1½	......	......	little	......	little	......	....
	33	6 f 4	82	....	1	......	15	......	......	......	......	......	1	½	½	......	......	little	......	......	......	....
	36	7 e 4	75	....	7	......	15	......	......	......	1½	1	......	......	little	......	little	little	......	......	......	....
	38	2 L 8	40	16	12	......	10	......	5	5	little	5	......	5	1½	......	½	......	......	......	......	....
	39	12 i 12	44	....	22	......	15	7	......	......	......	1½	......	7	2½	little	½	little	......	......	......	....
	43	7 g 15	40	30	8	......	5	9	......	......	......	3	......	3	1½	......	little	little	......	......	......	....
Basic phases of syenite	32	4 e 9	37	....	....	35	15	......	4	3	......	3	......	1	1	......	little	½	......	......	½	....
	40	5 e 2	48	....	....	15	12	......	......	......	......	......	20	3	1	......	½	little	little	......	......	....
Granitic syenite and granite	31	5 b 5	52	15	1	......	23	......	......	......	......	7	......	little	little	little	little	little	little	......	......	1
	47	7 f 2	45	10	5	......	38	......	......	......	......	......	1	......	½	......	little	little	......	......	......	....
	48	7 g 3	40	....	14	......	40	......	......	......	......	......	4	½	½	......	little	little	......	½	......	....
	46	13 b 7	44	....	15	......	30	......	2	3	......	4	......	......	1½	......	½	little	......	......	......	....
	49	1 k 2	32	15	5	......	40	......	......	......	......	2	4	1	½	little	little	little	......	......	......	....

Plate 12



Photomicrographs by W. J. Miller

Upper left figure. Part of slice of coarse granite from upper end of gorge one-half of a mile south of Keene. All is sliced (or sheared) and granulated quartz except a little scattering ilmenite and microperthite. Polarized light. Magnified 23 diameters.

Upper right figure. Part of slice of syenite from roadside at southeastern base of Cobble hill. Diallage crystal almost surrounded with a rim of granulated hypersthene. Embedded in microperthite and quartz. Ordinary light. Magnified 23 diameters.

Lower left figure. Part of slice of rather gabbroid Whiteface anorthosite from shore of river two-thirds of a mile southwest of Copperas pond. Magnetite or ilmenite surrounded with a rim of granulated garnet. Large somewhat rounded prisms above and below are apatite. Large white areas are mostly plagioclase. Ordinary light. Magnified 30 diameters.

Lower right figure. Part of slice of Keene gneiss from 1 mile east-northeast of Malcom pond. In the center, remarkable vermicular quartz intergrown with plagioclase. Ilmenite (black) above; orthoclase (gray) on right; plagioclase below; and quartz and orthoclase on left. Polarized light. Magnified 30 diameters.

No. 24, from Keene gneiss area just north of Keene; no. 25, by the road at southeastern base of Cobble hill; no. 27, quarry at southeastern end of Lake Placid; no. 28, by the road one-half of a mile north-northeast of Keene; no. 29, near the road one-half of a mile north of Keene; no. 30, by the road one-half of a mile west of Big Cherrypatch pond; no. 33, by the road one-third of a mile west of Copperas pond; no. 36, Whiteface brook, 1 mile from the lake; no. 38, 1½ miles north-northeast of Keene; no. 39, from tongue of syenite cutting Whiteface anorthosite 1 mile south of Morgan pond; no. 43, 1 mile west of High fall; no. 32, quarry by the road five-sixths of a mile north of Malcom pond; no. 40, by the river three-fourths of a mile west-southwest of Owen pond; no. 31, granitic syenite from middle eastern shore of Buck island in Lake Placid; no. 47, granite from the small area in Wilmington notch; no. 48, granite from the gorge at High fall of Ausable river; no. 46, granite porphyry from side of new road one-half of a mile southwest of Franklin Falls; no. 49, granite porphyry from the gorge one-half of a mile south of Keene.

There is no evidence that the syenite cuts the granite of the quadrangle, or vice versa, but a gradation from one into the other seems to be clearly shown in many places as, for example, on Catamount mountain ridge, on Wilmington mountain, and on the southern slope of Mt Whiteface. In a few cases the change from syenite to granite occurs within such short distances that the intermediate granitic syenite can not be mapped. Proof that the syenite is younger than the anorthosite has already been given.

As usual in the Adirondacks, this syenite is definitely known to be younger than the Grenville series. In certain localities the syenite contains masses of Grenville rocks as inclusions, this being particularly true near its borders with the Grenville. Such inclusions are nearly always arranged with their long axes parallel to the foliation of the syenite. Some of these inclusions are to be measured in inches, others in yards or rods, and still others are large enough to be separately indicated on the geologic map. Good examples of small inclusions may be observed on Cobble hill (east of Lake Placid village), and in Styles brook on the western border of the Grenville area. Some of the areas of mixed gneisses show Grenville rocks all cut to pieces by, and intimately associated with, syenite as, for example, 2 miles north-northeast of Keene, and 1 mile northeast of Keene.

Basic phase of the syenite. But one mass of rock of this kind has been separately represented on the accompanying geologic map. It lies in the valley of West Branch Ausable river east of Connery pond. The area is 1¾ miles long, with a maximum width of nearly

one-half of a mile. The origin and relations of this rock are not clear to the writer.

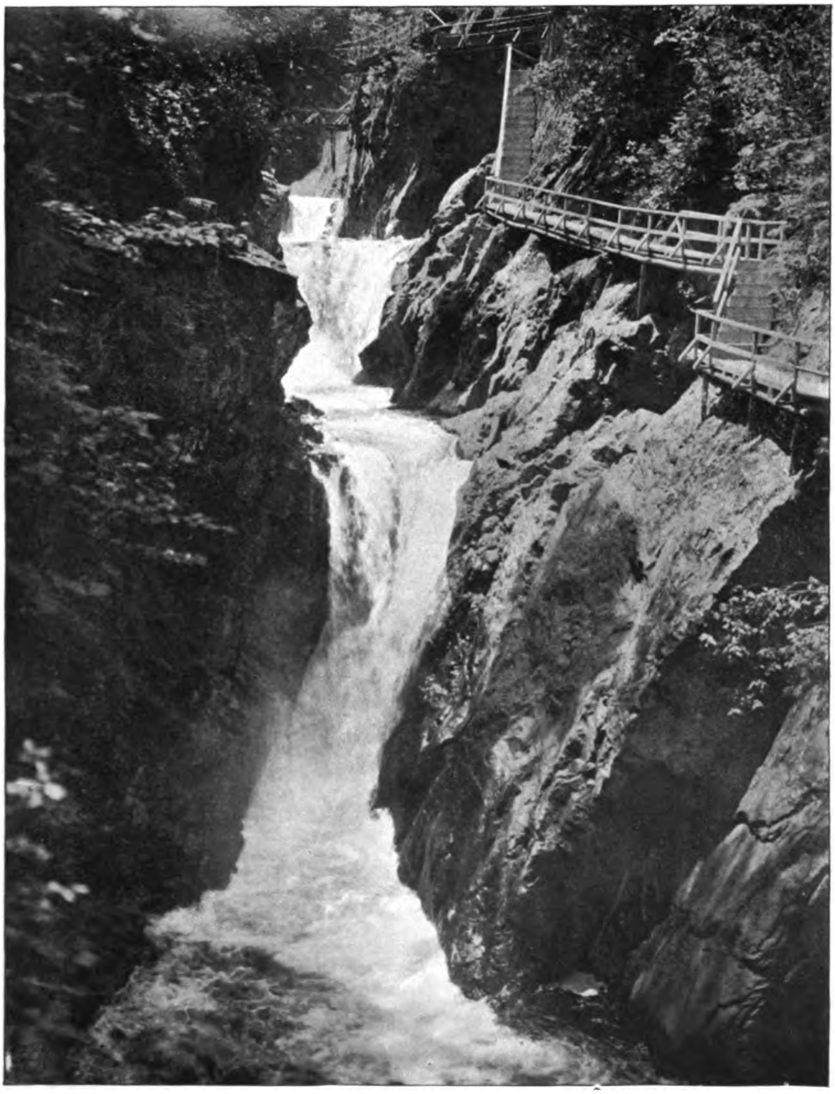
The main bulk of the rock is decidedly like the syenite in appearance, being medium grained nonporphyritic, moderately to very gneissoid, greenish gray where fresh, and weathering to brown. In the small quarry by the road near the southern end of the area, this type of rock is finely exposed. No. 32 of table 2 represents a thin section of rock from the quarry. No. 40, which represents a thin section of similar rock from the shore of the river 1⅕ miles farther north, is exceptional in being pinkish gray, probably due to weathering. Compared with the normal syenite, the average amount of plagioclase in this so-called basic phase of the syenite is seen to be higher. Thus the rock is more basic, being more like diorite than syenite. In every other way, however, the rock shows strong syenitic affinities.

Whether this so-called basic phase of the syenite is merely a differentiation phase of the adjacent normal syenite, or is a product of assimilation of some anorthosite by the syenite magma, the writer can not say. Its situation between the Keene gneiss (below described) and syenite strongly suggests the latter possibility. If the rock is an assimilation product it may be regarded as a sort of nonporphyritic outer zone of the Keene gneiss where the latter shades off into the normal syenite. In the field the relation of the rock to the Keene gneiss could not be positively determined because of lack of exposures along the border. Very similar rocks, usually regarded as basic differentiation phases of the normal syenite, are, however, known from various parts of the Adirondacks.

Granitic syenite. This rock is clearly intermediate between the normal quartz syenite and the granite or granite porphyry. It is an acidic facies of the syenite in which the quartz content is about 20 to 25 per cent. Since nothing like sharp boundaries exist, this percentage of quartz is only approximately represented in the twelve areas indicated on the geologic map. These areas, well scattered over the quadrangle, do not occupy more than 5 or 6 square miles. The rock is in every way much like the normal quartz syenite except for higher quartz content and frequent tendency to weather pink or pinkish gray.

On the eastern shore of Buck island in Lake Placid, where the pegmatite dikes cut the granitic syenite, the latter contains as much as 1 per cent of graphite in small flakes (see no. 31 of table 2). Since this granitic syenite is here closely associated with small

Plate 13



Photograph loaned by J. D. Washer, keeper of High fall and gorge

Looking upstream through the lower portion of the gorge of the West branch, Ausable river below High fall. The rock is pink granite intersected by dikes of diabase.

amounts of dark Grenville gneiss, it seems probable that the granitic syenite magma took up the graphite from the Grenville.

A fine big ledge, known as Pulpit rock, on the eastern shore of Lake Placid contains some inclusions of Grenville.

The hill just east of Connery pond is mostly a great barren ledge of quite homogeneous granitic syenite.

Granitic syenite as a transition rock between syenite and granite is well exhibited on the southern side of Mt Whiteface, and also on Catamount mountain ridge.

Granite. As already stated, this rock is, so far as could be determined, an acidic differentiation phase of the normal quartz syenite. Rather arbitrarily, when a rock of the syenite-granite series contains more than 25 per cent of quartz it is classed as granite. In a few instances the transition from syenite to granite takes place within too short a distance to permit mapping of the intermediate granitic syenite. Like the normal syenite, the granite is more or less clearly gneissoid, medium grained, and often considerably granulated. It is, however, nearly always pink or pinkish gray instead of greenish gray like the syenite. The mineralogical compositions of two typical granites are shown by nos. 47 and 48 of table 2.

Ten areas of this granite appear on the accompanying geologic map. Altogether they occupy only 8 or 9 square miles, and they are confined to the western half of the quadrangle.

The wide belt of granite on the southern side of Mt Whiteface is very typical medium to moderately coarse grained, pink to red, and distinctly gneissoid. Transition through granitic syenite to syenite is well shown, but on the north it appears to come sharply against the Whiteface anorthosite. A number of tongues of the granite sharply cut the Whiteface anorthosite at the eastern end, as already explained (see map).

At High fall and in the gorge just below the granite is pinkish, medium to moderately coarse grained, and very gneissoid.

The granite of the southern end of Wilmington mountain grades through granitic syenite into syenite.

About Silver lake, and also just west of Still brook, the granite clearly grades into the coarse granite porphyry.

Several outcrops of granite south-southwest of Woodruff fall, and also 1 mile southwest of Malcom pond, contain small, distinct inclusions of Grenville hornblende gneiss as lenses or irregular masses mostly parallel to the foliation of the granite.

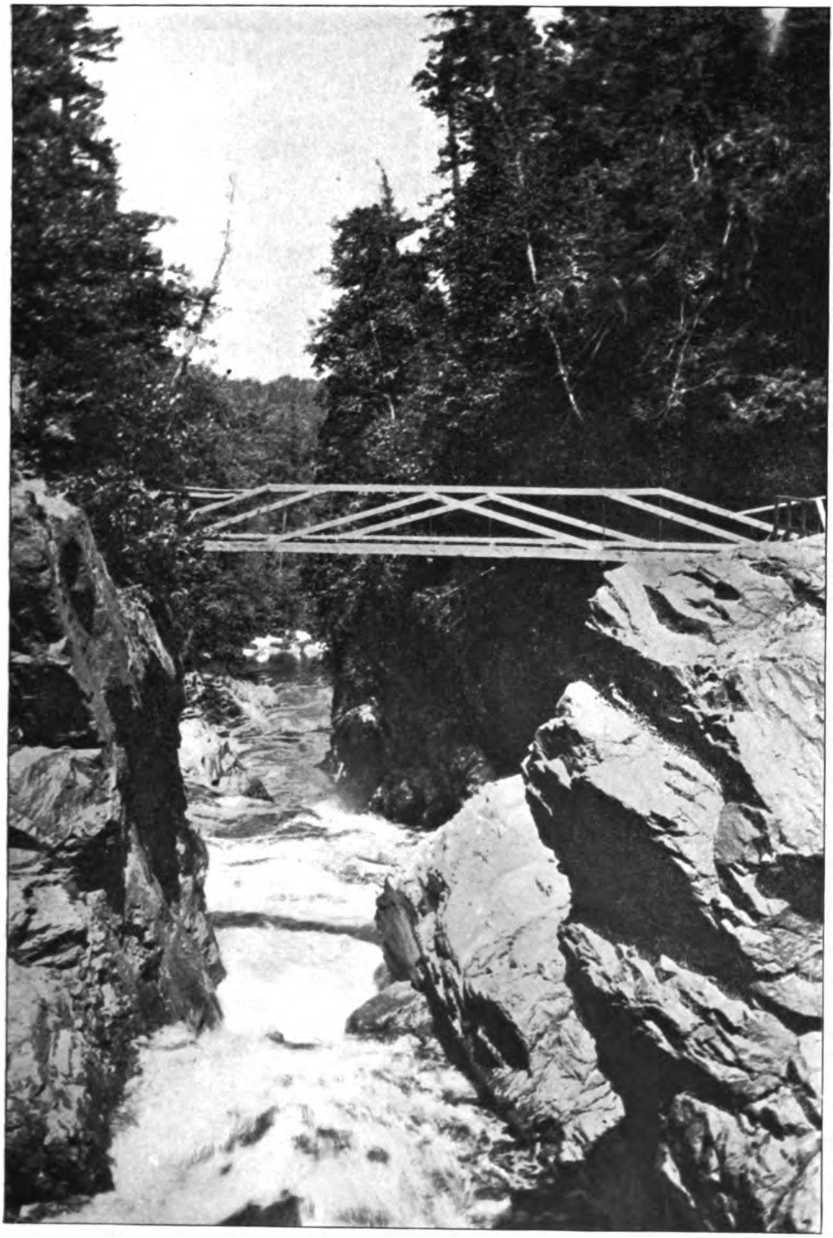
Granite porphyry. A body of coarse, usually porphyritic, granite occupies about 25 square miles of the northern portion of the quadrangle. Feldspar crystals nearly always range in length from one-fourth to 1 inch, and usually these stand out conspicuously as phenocrysts. Quartz individuals are often one-fourth to three-fourths of an inch long. Dark minerals seldom make up more than 10 or 12 per cent of the rock.

Most of the granite porphyry is more or less gneissoid, but locally there are considerable bodies of the rock which are practically devoid of foliation and not much granulated. Such nonfoliated rocks occur in big exposures on the hills in several square miles of the northwestern corner of the map area, on Fremont hill, and on the two hills respectively 2 and 3 miles east of Fremont hill. At the other extreme there are considerable developments of highly gneissoid coarse granite and granite porphyry. In these facies the feldspars are generally highly granulated, with the larger ones more or less flattened out into lenselike eyes or so-called "augen." The quartz crystals in these very gneissoid phases are remarkably flattened out into thin lenses, sometimes nearly an inch long. Fine examples of flattened quartz may be seen in the ledges from one-half to 1 mile southwest of Franklin Falls, 1½ miles north of Woodruff fall, and three-fourths of a mile north-northwest of West Kilns. The flattened quartz crystals are always arranged with long axes parallel to the foliation. In some localities the degree of foliation varies greatly within small areas. Thus, on the hillock 1¼ miles southeast of Fremont hill, nonfoliated, moderately foliated, and highly foliated coarse granites are associated. Similar variations in foliation occur on the hilltop 1 mile east of the south end of Silver lake.

The coarse granite very commonly weathers to a pink or pinkish gray, and more seldom to light brown. Fresh rock was obtained in but few localities as, for example, from a ledge recently blasted open by the roadside one-half of a mile southwest of Franklin Falls. Such rock is greenish gray. Whether or not much, if any, of the fresh granite is pink could not be determined.

The mineralogical composition of the granite porphyry is well illustrated by no. 46 of table 2, which represents a thin section of the typical, fresh, very gneissoid rock with large granulated "augen" of feldspar and highly flattened quartz individuals. This rock differs from the granite porphyries described by the writer from the central and southern Adirondacks by the absence of microcline, though possibly this mineral does occur in other portions of

Plate 14



W. J. Miller, photo, 1916

Looking down the gorge of the West branch, Ausable river from the foot-bridge just below High fall. The rock is pink granite intersected by several dikes of diabase parallel to the course of the stream.

the large area of granite porphyry. Hornblende appears to be a constant constituent, while pyroxene often fails. No. 49 of table 2 is from the small area of mixed rock in the gorge one-half of a mile south of Keene.

Like the other members of the syenite-granite series, inclusions of Grenville gneiss sometimes occur in this coarse granite as, for instance, on Catamount mountain, and on top of the hill 1 mile east of the south end of Silver lake.

It seems very clear, as a result of both field and laboratory studies, that the granite and granite porphyry are both only facies of a single great cooling magma. The perfect gradations from syenite through granitic syenite to granite and granite porphyry strongly support the view that the members of the syenite-granite series (except possibly the basic phase of the syenite) are differentiation products of a single great cooling magma. Possibly some of the granite may be distinctly older or younger than the syenite but, except for the small granitic dikes below described, no such rock could be proved to be present.

Granite, Aplite, and Pegmatite Dikes

The various acidic dikes which have been definitely located are represented on the geologic map (each dike by a number) there being twenty-one in all. There must be many others concealed under glacial drift, or hidden in the woods, or not discovered where actually outcropping. In some cases the age relations are not altogether clear.

Granite dikes. At dike localities 1 and 2 there are several pink granite dikes cutting anorthosite. No. 3 is a dike of pink granite 75 feet long cutting Whiteface anorthosite, but not with very sharply defined contacts. No. 4 is a dike 4 feet wide clearly cutting Grenville gneiss. Dike no. 11 is pink granite cutting Marcy anorthosite. At locality no. 12 several dikelike masses of granite are involved with syenite and Whiteface anorthosite.

Most of these dikes may be merely off-shoots from the great syenite-granite intrusive body, but some may possibly be considerably later in age.

Aplite dikes. Interesting dikes of aplite were observed. At no. 9, in the bed of the river east of Copperas pond, a dike of pink aplite, with several small tongues, clearly cuts a gabbroic, very gneissoid facies of the Whiteface anorthosite. A thin section of this aplite shows 20 per cent orthoclase, 20 per cent microperthite,

15 per cent albite, 44 per cent quartz, 1 per cent magnetite, and a little zircon. The rock is moderately gneissoid and variable in grain from medium to coarse. Possibly it is an acidic off-shoot from the neighboring syenite.

On the southern side of the top of Catamount mountain, a number of small nonfoliated aplite dikes lie parallel to the foliation of the coarse granite. Whether these are younger or older than the neighboring gabbro-diorite dikes was not definitely determined, but the aplites are probably the older.

At number 17, 1 mile west of East Kilns, a fine aplite dike 3 feet wide cuts a big ledge of coarse granite. A thin section shows the following mineral percentages: Microperthite, 58; microcline, 1; albite, 5; quartz, 35; biotite, 1; and very little garnet, apatite and zircon. The rock is not gneissoid. The fact that the contact against the granite is not very sharp strongly suggests that the aplite was intruded while the granite was still fairly hot.

At dike locality no. 18 several small aplite dikes cut granite.

Granite-pegmatite dikes. Nos. 5, 6, 7, 8, 10, 13, 14 and 16, indicated on the geologic map, are pegmatite dikes of the usual sort. They are nonfoliated and cut the Grenville, anorthosite, and syenite-granite series. No. 8 lies in contact with a diabase dike, and these two clearly cut syenite. No. 16 is a pegmatite dike 3 feet wide very sharply cutting across the foliation of one of the gabbro-diorite dikes below described. Within the Lake Placid quadrangle no pegmatite was observed cutting the gabbro stocks (below described), but in various portions of the Adirondacks dikes of such have been found to be intrusive into the gabbro. It is quite possible that these pegmatite dikes are not all of the same age, but all are doubtless younger than the syenite-granite series, most of them probably representing a late stage in the intrusion and cooling of the syenite-granite magma.

Syenite-pegmatite dikes. A much more unusual type of pegmatite dike was noted at several localities, namely, near Franklin Falls (dike no. 19); 1½ miles south of Wilmington (dike no. 20); and 1 mile southwest of Haselton (dike no. 21). These are very coarse-grained rocks consisting chiefly of irregular masses of microperthite and black hornblende (or pyroxene) up to several inches across. No quartz occurs. Dike no. 19 is 2 feet wide, cuts Whiteface anorthosite, and contains masses of magnetite 1 or 2 inches across. The contact against the country rock is not sharp. At no. 20 a number of pegmatite dikes from 1 to several feet wide cut Marcy anorthosite usually without sharp contacts.

These dikes consist almost wholly of microperthite and hornblende in large masses. It seems very clear that the pegmatites of this sort were intruded very soon after the intrusion of the anorthosite and that they are, therefore, distinctly older than the ordinary granite-pegmatites above described.

Keene Gneiss

General statements. One of the most interesting rocks of the quadrangle is locally developed as belts or irregular bodies along portions of the borders between the anorthosite and syenite-granite. Both the Marcy and the Whiteface types of anorthosite show such border rocks. There is very strong evidence, based upon field work and a study of thin sections, that this is really a transition rock between the anorthosite and the syenite or granite due to actual digestion or assimilation of anorthosite along its border by the invading syenite-granite magma. It is here proposed that this rock be called the Keene gneiss because a fine exposure of the typical fresh rock occurs by the road at the northern edge of the village of Keene. In view of the fact that many geologists maintain that there are no definitely proved cases of magmatic assimilation on considerable scales at least, the evidence furnished by these rocks of the Lake Placid quadrangle has been very carefully considered by the writer who is convinced that actual assimilation has taken place. In other words, the Keene gneiss seems to be quite certainly a good example of a "hybrid" rock, to use the term suggested by Harker, the English geologist, who has maintained that such rocks have been produced either by the mixing of two distinct magmas, or by the assimilation of solid rock by magmas. Fifteen areas of Keene gneiss are represented on the geologic map which accompanies this bulletin. Others probably exist but were not located owing to scarcity of outcrops or roughness of country in some places.

The typical Keene gneiss presents a different appearance from any of the other rocks of the region, and it is usually readily recognizable. The main body of the typical rock is medium grained, gneissoid, notably granulated, and looks much like a rather basic phase of syenite, but it contains scattering phenocrysts of bluish gray labradorite up to an inch in length. These phenocrysts, which are rounded and usually elongated parallel to the foliation of the rock, doubtless represent cores of crystals which survived the process of granulation. Locally the phenocrysts of labradorite are

absent or only sparingly present, ledges of such rock being very difficult to distinguish from a basic phase of syenite. Under the microscope, however, the distinction may generally be made. Where fresh the rock is greenish gray, and it weathers to brown.

The mineralogical compositions of selected samples of various phases of the rock are shown in table 3. Labradorite and andesine are always present, and oligoclase usually. Microperthite occurs in most of the specimens in varying amounts up to 30 per cent, and orthoclase in most specimens in varying amounts to over 50 per cent. A little quartz is generally present. All the thin sections examined show greenish gray monoclinic pyroxene, sometimes diallage. A little green hornblende nearly always occurs up to 14 per cent. Garnet varies from none to 12 per cent. Ilmenite (or magnetite) up to a few per cent never fails. Apatite and pyrite in small amounts always occur. N. L. Bowen, in a recent paper,[1] states that he has observed, in the transition rock from anorthosite to syenite, inclusions of potash feldspar which are small patches, uniformly oriented, and, in some cases, surrounded by areas of plagioclase differing from the crystal as a whole. A few slight suggestions of this sort of thing were noted by the writer, but certainly this is not a characteristic feature of the Keene gneiss thin sections examined.

Table 3 Thin sections of Keene gneiss

Slide no.	Field no.	Plagioclase	Microperthite	Orthoclase	Quartz	Monoclinic pyroxene	Diallage	Hornblende	Ilmenite or magnetite	Garnet	Apatite	Zircon	Pyrite	Titanite	Secondary calcite
3	4 f 8	ol.-Lab. 80	10	....	4	....	3	1	½	little	1	little	little	.....	....
10	7 f 7 a	ol.-Lab. 28	25	20	6½	6	...	...	2	12	¼	¼	.....	.....	....
11	14 g 4	An.-Lab.66	..	20	2	4	....	8	.....	.....	little	little	.....	.....	....
12	14 h 4	ol.-An. 48	20	...	9	5	....	14	1	.....	little	½	.....	little	2
41	16 j 7	An.-Lab.30	...	51	5	3	...	5	½	5	½	.....	little	.....	....
42	1 k 10 a	An.-Lab.70	20	..	1	3	2	2	1	½	¼	.....	¼	.....	....
45	1 k 10 b	ol.-Lab.40	32	10	....	2	8	6½	1	.....	½	.....	little	.....	....

No. 3, 1 mile east-northeast of Malcom pond; no. 10, 1 mile a little south of west of High fall; no. 11, one-half of a mile south of the summit of Catamount mountain; no. 12, one-half of a mile north of Franklin Falls; no. 41, in the brook 1¼ miles due west of East Kilns; nos. 42 and 45, by the main road at northern edge of the village of Keene.

[1] Jour. Geol. 25:221. 1917.

Areas in the vicinity of Keene village. The type locality of the Keene gneiss is a ledge by the side of the state road at the northern edge of the village of Keene where an excellent opportunity is afforded for the study of the rock and its relations to both anorthosite and syenite. All three of these rocks show as unweathered material in this one ledge which has been recently blasted open. The anorthosite, which occurs in minor amount, is the typical Marcy facies consisting mostly of dark, bluish gray labradorite up to an inch across embedded in some granulated feldspar, and associated with 10 to 20 per cent of ferro-magnesian minerals. The syenite is quite normal in every respect except that it is a little finer grained than usual. No. 24 of table 2 gives its mineral content. Most of the rock of the ledge, however, is clearly an assimilation product of syenite and anorthosite. This assimilation rock (Keene gneiss) exhibits at least three distinguishable facies. One of these is highly gneissoid with elongate cores of labradorite crystals as phenocrysts up to an inch long arranged parallel to a distinct foliation. Its mineral content is given as no. 42 of table 3. A second facies is only faintly gneissoid, with labradorite phenocrysts only roughly parallel to the foliation. Its composition is given as no. 45 of table 3, the presence of orthoclase and a greater amount of microperthite making this rock much more syenitic than the first facies. In the two facies just described, the phenocrysts of labradorite not only finely exhibit polysynthetic twinning, but they are also perfectly twinned according to the albite law, thus giving the freshly broken surface a striking appearance. Both of the facies are notably granulated, and the rounded phenocrysts are the uncrushed portions of what were once still larger crystals. A third facies, in minor quantity, is nonfoliated and contains no labradorite phenocrysts, but it does contain a few rounded red garnets up to an inch across. This third facies is the most syenitic of the three.

All three facies just described grade into one another and they are quite certainly only differentiates of a single cooling magma. Also it is important to note that the Keene gneiss is not sharply separated from the true syenite on one hand, and the true anorthosite on the other, but rather by narrow transition zones. All three facies of the Keene gneiss are certainly intermediate in composition between the syenite and anorthosite, the first one described having decided anorthosite affinities, the third having decided syenite affinities, and the second being very clearly intermediate

between the syenite and anorthosite. The conclusion, therefore, based upon the field relations and composition of the rocks is that we have here a true magmatic assimilation product, the invading syenite magma having actually incorporated and assimilated more or less of the anorthosite material. The close juxtaposition of syenite and Keene gneiss may be reasonably explained if we consider the syenite to have been an intrusion as an off-shoot of the great body of syenite magma into previously formed and cooling (or possibly solidified) Keene gneiss magma, the temperature then having been high enough only to permit fusion along a narrow border zone between the intruded and intrusive masses, thus accounting for the narrow transition zone between the two in the ledge. The foliation of the Keene gneiss is quite certainly an original structure due to magmatic flowage under pressure, and accordingly the marked differences in degree of foliation within this one outcrop are regarded as the result of differential magmatic flowage according to the principles explained beyond under the caption " Foliation."

Professor Kemp has informed the writer that rock similar to that just described was formerly visible in outcrop at the present sawmill site in Keene village, and the area of Keene gneiss is accordingly extended that far south on the geologic map.

The little area one-half of a mile east of Keene shows a variable lot of rocks, some being apparently Whiteface anorthosite, some rich in black minerals and garnet, and much containing large bluish gray labradorites in a very syenitic looking, crudely gneissoid, brownish-weathered rock like the typical Keene gneiss above described except for its brown weathering.

Oak ridge shows fine big exposures of a rock which, in the field, would be taken for a rather basic phase of syenite except for the large scattering bluish gray labradorites. It is, without doubt, a large scale mass of the Keene gneiss.

Good outcrops of typical Keene gneiss also occur in the small areas respectively 1 mile northeast; 2 miles west-northwest; and 4½ miles west of the village of Keene.

Areas near Upper Jay. In the area of over one-half of a square mile just east of Upper Jay, there are many very good exposures, certain of them of particular interest because they throw important light upon the origin and relations of the Keene gneiss. Near the top of the hill at the northeastern border of the area, Whiteface anorthosite and syenite in big exposures are separated by a zone, a few feet wide, of basic syenitelike rock with scattering bluish

gray labradorites. This is very clearly a transition zone of typical Keene gneiss produced by the assimilation of Whiteface anorthosite by syenite magma. On the little hill just south of the center of the area, several outcrops of quite typical Keene gneiss contain bands or lenslike inclusions of Whiteface anorthosite, the Keene gneiss magma, moving from a lower level where it was formed, evidently having penetrated or caught up inclusions of unchanged Whiteface anorthosite at the higher level. The Keene gneiss here contains many tiny red garnets, and the labradorite phenocrysts are very conspicuous on the weathered surfaces.

A little area, shown on the map 1¼ miles west of Upper Jay, is thought to be Keene gneiss, but the matrix of this rock is finer grained and more gneissoid than usual.

Sentinel range area. This long, narrow area extends east-west across the middle of the Sentinel range. It is about 4 miles long and nowhere over one-fourth of a mile wide. It is all in a rough, densely wooded country, but a good many outcrops make the mapping fairly satisfactory. Perhaps the most instructive ledges are on the little hill 1 mile northeast of Malcom pond. The top of this hill is quite typical Marcy anorthosite. On the southern side the rocks are variable, being mostly fine to medium grained, gneissoid and gabbroic in appearance with some closely involved basic syenitelike rock containing a few small, scattering labradorite phenocrysts, this latter being presumably Keene gneiss. Near the top of the hill, on the west side, the rock is coarser grained with few dark minerals, and this appears to be quite like typical Keene gneiss. All the types mentioned grade into one another.

On the hillside one-half of a mile southeast of the hill just described, there are outcrops of a moderately coarse-grained, rather gabbroic rock with some labradorite phenocrysts. Its mineralogical composition, given as no. 3 of table 3, shows that it should be classed as Keene gneiss with strong anorthosite affinities.

Good exposures of Keene gneiss may be seen in other portions of the areas mapped, particularly for a mile eastward from the summit of Sentinel range, where the typical rock forms a wide transition zone between the Marcy anorthosite on the north and the quartz syenite on the south.

Sunrise notch area. This, the largest area of Keene gneiss within the quadrangle, is about 3½ miles long and from one-half to two-thirds of a mile wide. It is a rock distinctly intermediate between Whiteface anorthosite and syenite. Most of the outcrops are quite typical Keene gneiss, though usually not strongly foliated.

It is generally medium grained with scattering labradorite phenocrysts, and weathered brown.

A locality of special interest is a cliff on the southern border of the area three-fourths of a mile east of the summit of Sunrise notch. Most of this rock is very gneissoid and only moderately gabbroic Whiteface anorthosite, a little finer grained than usual. Its mineral content is given as no. 20 of table 1. Within this rock there is a wide band of fine-grained, very gneissoid, gray rock with a reddish tinge due to numerous tiny garnets. The composition of this local band, given as no. 10 of table 3, causes it to be classed with the Keene gneiss, the high content of microperthite and orthoclase showing it to have strong syenite affinities. Its contact against the anorthosite is not very sharp. Evidently a dike or tongue of the Keene gneiss magma here intruded the Whiteface anorthosite near its border, and the temperature was high enough to cause fusion of the anorthosite walls of the dike or tongue.

The small area of Whiteface anorthosite one-third of a mile north of the locality just described, presumably represents a body of anorthosite which failed to become assimilated by the syenite magma.

Area west of East Kilns. This area, between 1 and 2 miles west of East Kilns, shows certain interesting and important features. Much of the rock, whose composition is given as no. 41 of table 3, has strong syenite affinities because of its high orthoclase content.

Near the middle of the northern boundary, syenite contains Whiteface anorthosite inclusions as bunches, lenses and bands from 2 or 3 inches to several yards long, the boundaries of the inclusions usually not being very sharp. Evidently very little assimilation of the anorthosite took place here.

Along the northwestern side several ledges are very gabbroic in appearance, in some places very gneissoid and in others not. Locally there is intimately associated syenite and Whiteface anorthosite. Apparently these ledges show the effects of partial digestion or assimilation of anorthosite by the syenite magma.

Along the main brook, for one-fourth of a mile after it enters the area, there are good exposures of homogeneous, scarcely gneissoid Keene gneiss, with the phenocrysts of labradorite not so large as usual. This rock, whose composition is given as no. 41 of table 3, has strong syenite affinities because of its high orthoclase content. In this portion of the area, syenite magma quite certainly completely assimilated more or less anorthosite.

The little hill in the eastern portion of the area consists of rather mixed rocks, but it is mostly Keene gneiss with large labradorites. At one place fairly coarse granite is intimately associated with gabbroic Whiteface anorthosite with local development of what appears to be an assimilation product of the two containing some quartz. Small masses of Grenville gneiss are also commonly involved with the rocks of this hill.

Other areas. The narrow band of Keene gneiss at the southern base of Catamount mountain contains large labradorites but it is scarcely gneissoid. No. 11 of table 3 gives its mineral content.

In the small area one-half of a mile north of Franklin Falls, a medium-grained, rather gabbroic, gneissoid rock, without phenocrysts, has the composition of Keene gneiss as shown by no. 12 of table 3. This rock grades into gabbroic Whiteface anorthosite, but its relation to the nearby granite could not be determined.

The area just north of Owen pond shows big ledges of homogeneous, typical Keene gneiss.

The small area 1½ miles south-southeast of The Flume shows Keene gneiss closely associated with much syenite and some Whiteface anorthosite.

Significance of the distribution of the Keene gneiss. That the Keene gneiss is actually an assimilation product of the fusion and digestion of anorthosite by syenite or granite magma is regarded as proved by the evidence above presented. But such rock is not universally present as a transition or border rock between anorthosite and syenite or granite. For instance, the long boundaries between the Whiteface anorthosite and granite of Mt Whiteface, and between the Whiteface anorthosite and syenite from the southern side of Mt Whiteface to west of Knapp hill, were crossed at many places without noting any rock like the Keene gneiss. As seen on the map, other areas also show an absence of Keene gneiss as a border rock. It is possible that some masses of Keene gneiss may have been overlooked in the rough, densely wooded country, or that some may exist under cover of glacial and postglacial deposits, but, in view of the detailed survey, it is certain that any such masses of Keene gneiss are relatively small. How is this difference in distribution of the Keene gneiss to be accounted for? Also why do the borders between the Grenville and syenite-granite series, as well as in the mixed gneiss areas of Grenville and syenite-granite, show little or no evidence of magmatic assimilation? The writer believes that the answer to these questions may be found in the temperature relations of the rocks at the time of the intrusion

of the syenite-granite series. If we consider that the great mass of anorthosite was still at a relatively high temperature, though not necessarily molten, at the time of the syenite-granite intrusion, it would have been only necessary for the syenite-granite magma to have raised the temperature of the borders of the intruded anorthosite comparatively little to have effected actual assimilation.

The tongues of syenite cutting Whiteface anorthosite on Wilmington mountain, and the tongues of granite cutting Whiteface anorthosite on Mt Whiteface (described on page 33), furnish important evidence in support of this view, because these tongues or dikes, instead of being in real sharp contact with the anorthosite, show very narrow transition zones due to slight fusion of the anorthosite. Now, it does not seem at all probable that even small amounts of relatively cold anorthosite could have been fused and assimilated by such small masses of intrusive magma, but with the anorthosite at a high temperature, though not really molten, its borders might very conceivably have been fused. Thus, if we make the very simple and plausible assumption that the anorthosite was still very hot (though not necessarily molten) when the syenite-granite magma was intruded, or, in other words, that this latter magma was forced up comparatively soon after that of the anorthosite, the usual strong objection to magmatic assimilation, namely, that a magma does not possess a sufficiently high temperature to raise relatively cold country rock to the point of fusion, is distinctly obviated.

Where no Keene gneiss occurs along the borders, it may be plausibly conceived that either the anorthosite, or the syenite-granite, or both, may not have been hot enough to permit assimilation. Also, in harmony with this hypothesis, the failure to find any considerable assimilation of Grenville either along its borders with, or where involved with, the syenite-granite series may be explained on the basis of a temperature of the Grenville too low to have permitted any more than comparatively slight assimilation by the invading syenite-granite magma. It should be borne in mind, however, as pointed out in a recent paper by the writer, that local assimilation of Grenville was not uncommon in the Adirondack region.[1]

In the mixed rock areas near the center of the quadrangle, where anorthosite has been cut to pieces by intrusions of syenite, the few contacts observed are not very sharp. Apparently, in these areas

[1] Geol. Soc. Amer. Bul. 25:254-63. 1914.

either the syenite magma or the anorthosite, or both, were not hot enough, or the syenite was not in sufficient bulk, to effect more than slight fusion of the immediate borders of the invaded anorthosite.

Another important fact is that, in the field, the Keene gneiss by no means universally forms a narrow zone or belt with syenite-granite directly adjacent on one side and anorthosite on the other. A fine case in point is the eastern part of the Sunrise notch area where the Keene gneiss for 1½ miles lies between granitic syenite on one side and syenite on the other. A different case is the Oak ridge area which is bordered on the south by Whiteface anorthosite, and on the north by Grenville, Marcy anorthosite and syenite. How can areas of this sort possibly be explained by Bowen's hypothesis, which assumes that the anorthosite was never an active magma but that it was formed by sinking of plagioclase crystals with the development of a transition rock (called Keene gneiss in this bulletin) occupying a position distinctly intermediate between the syenite-granite and the anorthosite? Is it not much more in harmony with the field relations to conceive that Keene gneiss magma was produced by assimilation at a lower level and then rose to invade previously formed Grenville and anorthosite, or moved upward flanked on either side by syenite or granite? Also are not elliptical areas like those just east of Upper Jay and 1½ miles west of East Kilns much more satisfactorily accounted for by the latter hypothesis than by Bowen's hypothesis? Again, do not the inclusions of anorthosite in the Keene gneiss (see above descriptions) strongly support the writer's view that the Keene gneiss, in some places at least, moved upward as a true magma?

Finally, it should be noted that the Keene gneiss accompanies both the Marcy and the Whiteface types of anorthosite, being about as common with one as with the other. Within the Lake Placid quadrangle, then, the temperature relations between the syenite-granite and Marcy anorthosite on the one hand, and the Whiteface anorthosite on the other, do not seem to have been notably different during the syenite-granite intrusion. The presence or absence of the Keene gneiss appears to be irrespective of whether the syenite-granite borders the Marcy or the Whiteface anorthosite.

Comparison with Cushing's southwestern Franklin county basic syenite. In Cushing's report on the geology of the Long Lake quadrangle, he describes a basic phase of the syenite which grades into a rather fine-grained, even granular, gneissoid rock with few feldspar phenocrysts, and dark minerals often equaling or

exceeding the feldspar in quantity. Some of the feldspar is microperthite and some oligoclase-andesine. "The most of the basic syenite, and all of the more gabbroic of it, is in close association with the anorthosite border. . . . Now the syenite is unquestionably younger than the anorthosite, and the observed relations seem to point to the conclusion that the change (in the syenite) is due to the actual digestion, by the molten syenite, of material from the (anorthosite) gabbro."[1] The Keene gneiss of the Lake Placid region differs in being coarser grained, distinctly porphyritic, and not so rich in dark minerals, but both Cushing's basic syenite and the Keene gneiss are intermediate in position and composition between the anorthosite and the syenite-granite series in their respective regions, and the writer believes that Cushing's suggested explanation is the correct one.

Another rock, earlier described by Cushing[2] from a railroad cut nearly 5 miles north of Tupper Lake Junction, is regarded by him as intermediate between the syenite and the anorthosite. Judging by the description, this rock is, in almost all respects, similar to the typical Keene gneiss except that the labradorite phenocrysts are not so large. This work of Cushing, therefore, strongly supports the idea that the Keene gneiss is a magmatic assimilation product.

Mixed Rocks

Grenville or amphibolite and Whiteface anorthosite mixed gneisses. Under this caption there are described several areas in which Grenville rocks and probably some ortho-amphibolite have been cut to pieces by, and are more or less intimately associated with, the Whiteface type of anorthosite. In some places the Grenville or amphibolite predominates, and in others the anorthosite, but the two rocks are too closely associated to be satisfactorily separated on the geologic map. During the writer's recent survey of the Lyon Mountain quadrangle next to the north much gabbro-amphibolite older than the syenite-granite and probably older than the anorthosite was encountered. Quite likely then at least some of the amphibolite of the Lake Placid quadrangle is to be placed in the same category.

The largest area, over 3 miles long, lies between Keene and Upper Jay. It is traversed by the East Branch Ausable river. For most part, the rocks of this area are Grenville hornblende gneiss

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[1] N. Y. State Mus. Bul. 115, p. 479. 1907.
[2] N. Y. State Mus. Rep't 54, 1:r43 and r68. 1902.

and pyroxene gneiss which have been cut to pieces by intrusions of Whiteface anorthosite, the Grenville and the anorthosite nearly always being clearly recognizable as such. Very distinct small inclusions of Grenville gneiss in the anorthosite were noted in various ledges, particularly along the road between 1 and 2 miles south of Upper Jay; by the road 1¼ miles southwest of Upper Jay; and 2¼ miles due north of Keene in the western corner of the large area.

Another type of mixed gneiss from the above-mentioned area is of particular interest. This rock shows in good outcrops west of the river between 2 and 3 miles north of Keene; in the quarry by the road 3¼ miles north of Keene; and by, or close to, the road between one-half and three-fourths of a mile north of the quarry (see map). The best place to study this rock is in and around the quarry. In the quarry the rocks are Grenville hornblende and pyroxene gneisses, more or less intimately involved with Whiteface anorthosite. Much of the rock is a true injection gneiss, the Grenville gneiss having been so intimately penetrated by the anorthosite magma that the small hornblende and pyroxene crystals were mostly separated from each other and enveloped in the molten mass parallel to the magmatic currents, thus giving to the resulting gray, medium-grained rock a clearly defined foliation. Some portions of this rock are richer in dark minerals than others, and some portions show lenselike masses or bunches of dark minerals as distinct inclusions 1 or 2 inches long which were enveloped in the magma without being broken up. This rock contains occasional light bluish gray labradorite crystals up to an inch in length, and numerous tiny grains of titanite. A thin section of this injection gneiss reveals the following mineral percentages: andesine to labradorite feldspar, 58; green monoclinic pyroxene, 30; green hornblende, 10; titanite, 1½; biotite in tiny flakes, ½; and very little zircon. Another slide is similar, but it has several per cent of quartz in one narrow band. Locally, where the anorthosite greatly predominates, the rock is much coarser grained and the dark minerals are more irregularly arranged so that the foliation is not so pronounced. It is very evident that Grenville gneiss has here been more or less intimately injected by Whiteface anorthosite magma, but there is no indication whatever of actual digestion or assimilation of the Grenville by the magma, the crystals and fragments of the Grenville always showing sharp contacts against the enveloping anorthosite.

In the small area one-half of a mile east of Keene, the Grenville gneiss occurs as bands or inclusions in the anorthosite.

The area 2 miles long on the southern end of Wilmington mountain shows mostly Whiteface anorthosite, but nearly every outcrop contains so many inclusions of Grenville, chiefly green pyroxene gneiss, that it has seemed advisable to map this as an area of mixed rocks. Injection gneisses like those just described above were not noted. The small area just to the north contains similar rock.

Along the road just east of Franklin Falls there are some instructive ledges of Grenville and Whiteface anorthosite mixed gneisses. One phase of this rock is white, medium-grained Whiteface anorthosite (practically all andesine to labradorite) containing approximately 20 per cent of irregular lenslike masses and bunches of dark monoclinic pyroxene crystals, these masses ranging in size from mere specks to an inch or two long and roughly parallel, causing the rock to have a crude foliated structure. A thin section shows a little ilmenite and apatite. Closely associated with this rock is a true injection gneiss which is gray, medium grained and clearly foliated. In thin section it reveals the following mineral percentages: andesine to labradorite, 82; hornblende, 9; green and colorless monoclinic pyroxene, 7½; biotite, 1; and ilmenite, ½. Still another phase of the rock from the same ledge is very similar in mineral composition to the last phase described, but it is finer grained and contains several per cent of pale-red garnets in small, scattering grains. It is very evident that this rock, with its several facies, is a border phase of the considerable body of Grenville just to the east (see map) where it has been penetrated more or less intimately by the Whiteface anorthosite magma.

The small area bordering the Grenville one-half of a mile north of Franklin Falls has a big ledge of gray, medium-grained, well-foliated injection gneiss, similar to those above described, with scattering light bluish gray labradorites up to nearly an inch long.

By the road 1⅓ miles north-northeast of Franklin Falls a single outcrop exhibits streaks and narrow bands of Grenville rusty biotite gneiss closely involved with Whiteface anorthosite parallel to the foliation of both.

At the edge of the quadrangle just east of Silver lake good exposures show dark Grenville gneisses all shot through by Whiteface anorthosite.

Along the border between the Whiteface anorthosite and dark Grenville gneiss east of the gabbro at the southern base of Catamount mountain, the anorthosite contains streaks and bands of the

D. W. Johnson, photo, 1916

View in the upper end of the gorge of the East branch of the Ausable river, one-half of a mile south of Keene. Looking eastward. The rock is mostly Whiteface anorthosite cut by granite. Crossed hammers lie upon the dike of diabase.

Grenville due to cutting to pieces of the Grenville by the anorthosite magma along the border. This rock is not separately represented on the geologic map.

In the area of Whiteface anorthosite along the river west of Malcom pond several ledges exhibit Grenville closely involved with the anorthosite.

Grenville or amphibolite and syenite-granite mixed gneisses. In five areas shown on the map, the Grenville or amphibolite and syenite or granite are so closely associated that the delimitation of these rocks was not found to be practicable.

The area bordering Lake Placid on the east shows, along the lake shore, some ledges of pink granitic syenite with many long, narrow inclusions of dark hornblende gneiss roughly parallel to the foliation. Toward the interior of the area, there are some outcrops of nearly pure granite syenite, and others which are very gneissoid, rather basic looking, almost banded syenitic rocks which have resulted from more or less fusion of layers of dark gneiss by the syenitic or granitic magma. In some of these ledges there exist rather well-defined bands or layers of dark gneiss not over a foot thick where fusion has not been so effective.

At the map edge southwest of Keene, the area of mixed gneiss seems to show a predominance of syenite, but there are a good many outcrops of light and dark-gray Grenville gneisses. In some exposures the syenite and Grenville are rather closely associated, but, as a rule, the relationships of the rocks are not well exhibited.

One mile northeast of Keene the small area of mixed gneisses well exhibits intimately associated Grenville light and dark gneisses and syenite. Streaks and bands of Grenville are in some places more or less fused in.

In the area 2 miles a little west of north of Keene, syenite predominates, but considerable quantities of Grenville are involved with it, often having been more or less fused in. On top of the hill there seems to be a little Whiteface anorthosite as bands or inclusions parallel to foliation of the syenite.

The whole hill north of Cranberry pond is a mixture of fine to medium-grained, gneissoid, pink granite and hornblende gneiss, sometimes one and sometimes the other predominating. The hornblende gneiss (or amphibolite) occurs as bands in the granite parallel to the foliation. This dark gneiss is either Grenville or metagabbro, probably the latter.

Whiteface anorthosite and syenite-granite mixed gneisses. Four areas of mixed rocks of this sort are shown on the geologic

map. They represent masses of Whiteface anorthosite which have been more or less shot through, and cut to pieces, by syenite or granite. Individual outcrops within these areas are usually either good anorthosite or good syenite or granite, but they are too much involved to be separately mapped.

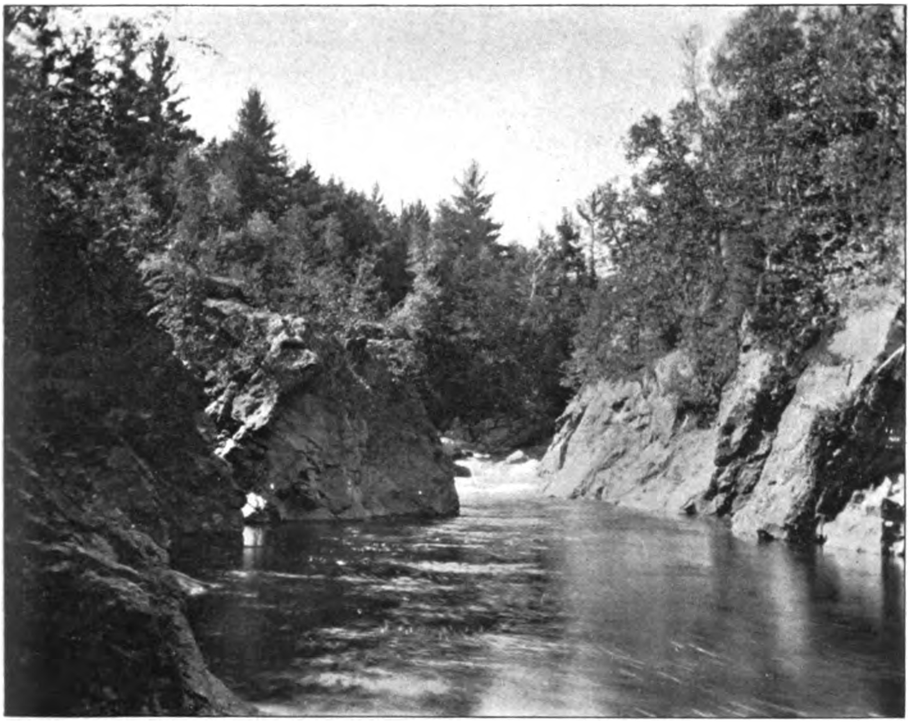
The largest area, extending from 1 to 3 miles east of Wilmington notch, is quite typical. There are many outcrops of clearly recognizable Whiteface anorthosite and of syenite with contacts visible at several places. Such contacts as, for example, on the ridge at the northwestern border of the area, are usually not perfectly sharp as though some fusion of the anorthosite by the syenite magma took place along the immediate borders between the two rocks. Actual fusion on a considerable scale did take place on the eastern side of the area as shown by the small body of assimilation rock (Keene gneiss) on the map. This whole area is a fine illustration of a mass (about 1½ square miles) of Whiteface anorthosite cut through by many intrusions of syenite of considerable size, but where apparently the temperature of one or the other, or both, of the rocks was not high enough to permit more than slight fusion of the anorthosite along the contacts.

The long, narrow area traversed by the river between High fall and The Flume contains a number of interesting exposures along the river. The Whiteface anorthosite has been badly cut through by intrusions of syenite, such phenomena being well exhibited in ledges by the river within one-third of a mile east of High fall. Small inclusions of Whiteface anorthosite in the syenite and parallel to its foliation occur in a ledge by the river one-half of a mile southwest of The Flume. An 8-foot boulder of syenite near the base of Little High fall, one-third of a mile east of High fall, contains several distinct inclusions of Whiteface anorthosite without very sharp contacts against the syenite.

The little area near the eastern end of Wilmington notch contains mostly good syenite with considerable Whiteface anorthosite as bandlike inclusions through it.

In the gorge of the river one-half of a mile south of Keene, there are excellent outcrops of Whiteface anorthosite cut by a considerable mass of coarse, rather porphyritic granite, with small tongues of the granite extending into the anorthosite. The anorthosite is the quite normal Whiteface type and clearly gneissoid. The granite is pinkish brown, gneissoid, and medium grained with scattering phenocrysts of feldspar. Much of the mixed rock here is badly broken up due to crushing in a fault zone (see plate 21). These

Plate 16



W. J. Miller, photo, 1915

The gorge of the East branch, Ausable river, one-third of a mile south of Keene. Looking south upstream. The rock is mostly Whiteface anorthosite.

crushed rocks are notably granulated, and in thin section the crushed granite shows very interesting examples of sliced and granulated quartz (see plate 12).

Gabbro-diorite Dikes

These very interesting dikes show considerable variation in mineralogical composition, but all of them may be classed as orthoclase gabbro-diorites. No rocks of this sort have ever been observed by the writer elsewhere in the Adirondack region. Altogether ten or twelve dikes were found, eight or nine on Catamount mountain, and two on the mountain 1½ miles north-northeast of East Kilns. These dikes are certainly younger than the coarse granite of the syenite-granite series, and older than the diabase, and some, at least, of the pegmatite, dikes. Whether they are older or younger than the gabbro stocks could not be determined.

Five or six of these dikes at or near the summit of Catamount very clearly cut the great bare ledges of granite for distances up to one-fourth of a mile. They vary in width from 2 to 30 feet, those toward the very summit all being over 20 feet wide. The strike of the dikes is roughly parallel to the foliation of the granite but it varies from N 10° E to N 50° E, the latter being the strike of the large dike which lies just below the summit and reaches one-fourth of the way down the mountain. The dikes are badly weathered (much more so than the granite) to brownish gray, so it is impossible to obtain good specimens of fresh rock. Contacts against the granite are rather sharp, and the dikes stand in practically vertical position. Two wide dikes just below the summit are weathered and eroded out leaving clear-cut trenches in the granite, these trenches being visible from the base of the mountain. All the rock is somewhat gneissoid, but the larger dikes are usually clearly finer grained and more gneissoid to almost schistoid at the borders. The most common facies of the dike rock is fine to medium even grained with mineralogical composition shown by no. 57 of table 4. Another facies is almost medium, even grained, and looks something like a basic phase of the syenite. Its mineral content is given as no. 56 of table 4. Least common is a fine-grained facies with scattering flakes of biotite each several millimeters across. Its mineral content is shown by no. 59 of table 4. As already stated, it was not positively determined whether the small aplite dikes in the immedi-

ate vicinity are younger or older than the gabbro-diorite dikes but, since the aplites are more strictly parallel to the foliation of the granite and not so sharply separated from it, it is probable that they are the older. Since the granite is only moderately foliated and the aplite not at all, it seems evident that the foliation of the gabbro-diorite dikes, especially near the borders, is the result of magmatic flowage rather than of regional pressure.

At the top of the ridge one-half of a mile northeast of the summit of Catamount mountain, there are three more of the gabbro-diorite dikes. The middle one is fully 40 feet wide and distinctly gneissoid. All three strike about N 20° E. A diabase dike 3½ feet wide, and a pegmatite dike 3 feet wide, each cuts obliquely across the largest of the gabbro-diorite dikes.

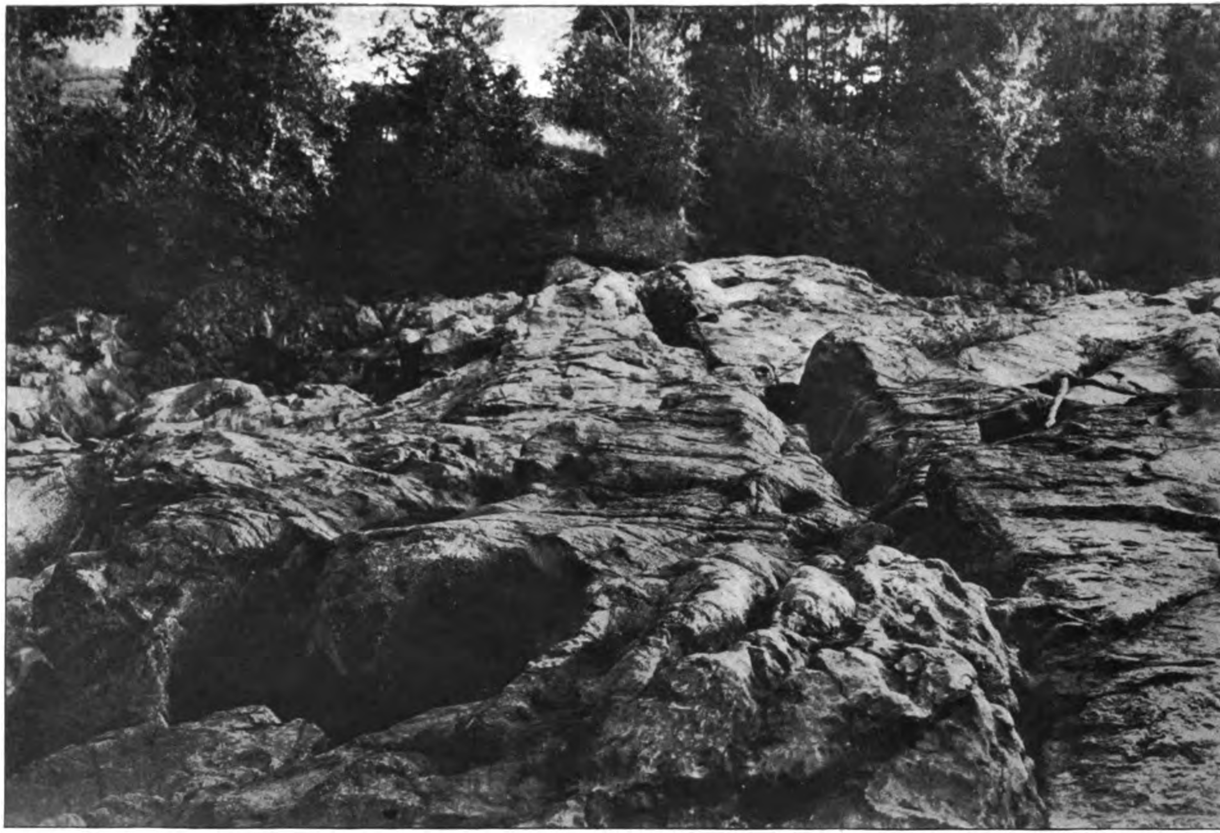
On the mountain 1½ miles north-northwest of East Kilns, two more gabbro-diorite dikes, presumably of the same age as those above described, show good contacts against the coarse granite. Each dike is about one-third of a mile long. The larger one is fully 100 yards wide, and the other is much narrower, being reduced to a width of only 1 foot at the western end where it very sharply cuts the granite. Fresh rock from the larger dike is dark greenish gray, and it weathers to a brownish gray. It is fine to medium grained and moderately gneissoid. It looks very much like a very basic facies of syenite, but its high content of albite and pyroxene (see no. 58 of table 4) makes it distinctly different. It differs from the Catamount gabbro-diorite by its high percentage of monoclinic pyroxene.

Table 4. Thin sections of gabbro-diorite

Slide no.	Field no.	Microperthite	Orthoclase	Plagioclase	Monoclinic pyroxene	Diallage	Enstatite	Hypersthene	Hornblende	Biotite	Ilmenite	Apatite	Zircon
56	15 g 5 a	50	....	Ol.-An. 25	......	....	....	10	12	1	1½	½	little
59	15 g 5 b	....	18	Alb. 32	......	....	....	24	20	4	1½	½	......
57	15 g 4	18	18	Alb. 17	......	½	3	40	......	1	2	½	......
58	17 k 2	....	10	Alb. 50	28	6	....	2	1	2	1½	½	......

Nos. 56, 59 and 57, from the top of Catamount mountain; no. 58, from top of mountain 1½ miles north-northwest of East Kilns.

Plate 17



D. W. Johnson, photo, 1916

Whiteface anorthosite and granite mixed gneisses in the bed of the East branch, Ausable river, one-half of a mile south of Keene. Looking southeast.

Gabbro and Metagabbro

Seven gabbro masses are represented on the accompanying geologic map. These are in most respects quite like the usual gabbro of this age throughout the Adirondacks. A rather full account of the typical gabbro is given in the writer's State Museum report on "The Geology of the North Creek Quadrangle." Most of the gabbro masses of the Lake Placid quadrangle appear to occur as true stocks rather than as dikes. No tongues or branches from them were observed to extend into the country rocks. The stocks all have rounded or elliptical ground plans, and range in size from one-eighth of a mile across to 1 mile across. Most of the gabbro bodies are certainly intrusive into, and therefore, younger than, the syenite-granite series, but, judging by experience in the Lyon Mountain quadrangle some may be older than the syenite-granite. They are clearly older than the diabase dikes. Whether they are older or younger than the gabbro-diorite dikes above described could not be positively determined, but they are probably younger.

The gabbro bodies nearly all consist of nongneissoid interior facies with more or less well-developed diabasic texture, and very gneissoid (amphibolitic) border facies without diabasic texture. The nongneissoid diabasic textured gabbro is generally easily distinguished from the other Adirondack rocks, but the amphibolitic border facies often greatly resemble certain of the Grenville hornblende gneisses.

The fresh rock is dark gray, which, on weathering changes to deep brown. Most of the rock is medium grained. About equal amounts of plagioclase (chiefly labradorite) and dark minerals make up the main bulk of the rock. Portions or all of the labradorite crystals are often filled with tiny dark specks of some unknown mineral arranged parallel to the twinning bands. Most prominent of the dark minerals are monoclinic pyroxene, hypersthene and hornblende. Garnet seldom fails, and it often constitutes 10 or 15 per cent of the rock. The pyroxene and garnet are commonly much granulated, the crushed garnet generally either forming rims around feldspar or granulated pyroxene, or borders between feldspar and granulated pyroxene. Olivine occurs in at least two of the masses, this mineral being rather uncommon in Adirondack gabbros. Slide 52 of table 5 shows olivine with successive rims of granulated hypersthene, feldspar and garnet (see lower right figure of plate 18). Table 5 gives the mineralogical compositions of several typical gabbro bodies.

Table 5 Thin sections of gabbro

Slide no.	Field no.	Plagioclase	Monoclinic pyroxene	Diallage	Hypersthene	Olivine	Hornblende	Biotite	Garnet	Ilmenite or magnetite	Pyrite	Apatite	Zircon
26	5 c 1	Ol.–Lab. 50	3	....	20	....	24	......	1	1	little	½	little
53	4 c 9	An.–Lab. 50	12	....	12	....	15	little	10	½	little	......	.....
54	4 c 3	An.–Lab. 50	5	....	13	....	25	little	......	1½	little	little	.....
52	4 m 2	An.–Lab. 50	20	5	....	8	1	½	14	1	½	......	.....
55	14 g 2	Lab. 50	10	....	17	1	7	4	10	......	little	......	.....

Nos. 26, 53 and 54, from Pulpit mountain gabbro mass; no. 52, from southern side of gabbro 2½ miles south-southeast of Upper Jay; no. 55, from gabbro at southern base of Catamount mountain.

Most of the Pulpit mountain gabbro mass is gneissoid, only a relatively small portion of the interior being nonfoliated and with a diabasic texture. Nos. 26, 53 and 54 of table 5 are from this stock.

The largest body, from 2 to 2½ miles south-southeast of Upper Jay, lies only partly within the limits of the quadrangle. Most of the rock is medium to moderately coarse grained with good diabasic texture, and a gneissoid border facies is more or less well developed. It is an olivine gabbro (see no. 52 of table 5). A small diabase dike, with nearly north-south strike and dip 60 degrees east, sharply cuts the gabbro near the southern margin.

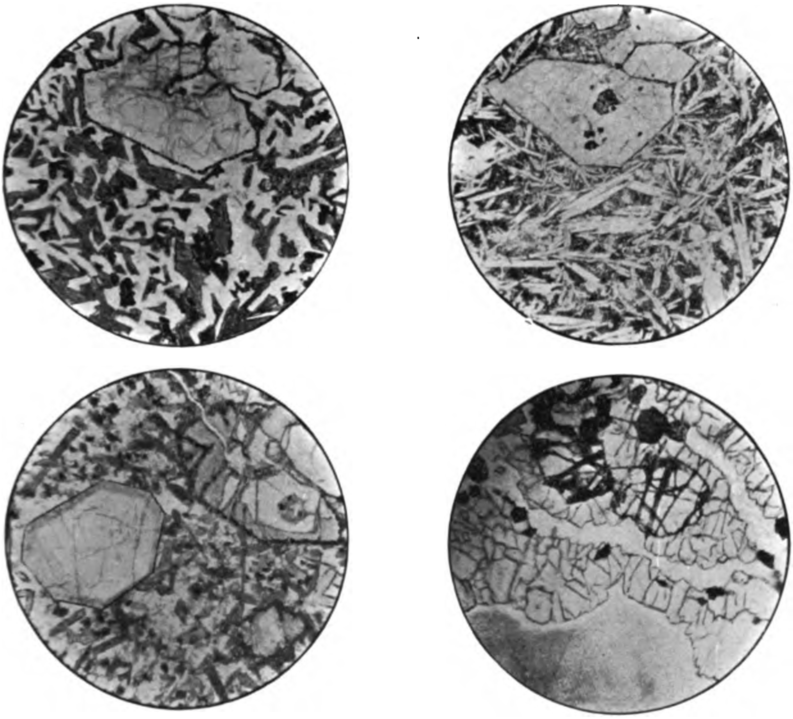
A small diabase dike sharply cuts the small gabbro mass 1 mile west of East Kilns.

The other gabbro masses are quite typical in every way. The gabbro at the southern base of Catamount mountain clearly exhibits its relations to Whiteface anorthosite, Keene gneiss, and granite, all three of which it sharply cuts.

Diabase Dikes

General features. Without counting two or more dikes close together within practically single outcrops, sixty-one diabase dikes were found within the quadrangle. These are all located and numbered on the accompanying geologic map. Without question still others exist, but they are either effectually concealed or they escaped detection in the rough wooded country. Such diabase dikes are known to occur throughout the Adirondack region. They are the youngest of the Precambrian rocks, and they always sharply

Plate 18



Photomicrographs by W. J. Miller

Upper left figure. Part of slice of gabbro from dike no. 5, one-half of a mile south-southwest of Owen pond. Shows very fine diabasic texture. Toward top, a large phenocryst of olivine with a thin rim of magnetite or ilmenite. Dark gray angular patches, brown augite; black patches, magnetite or ilmenite; white material, plagioclase. Ordinary light. Magnified 23 diameters.

Upper right figure. Part of slice of diabase from quarry at southern base of Hamlin mountain. Toward top, augite phenocryst with inclusions black patches) of pyrite. White laths are labradorite crystals embedded in a black glassy groundmass. Ordinary light. Magnified 30 diameters.

Lower left figure. Part of slice of diabase from dike at south end of gorge one-half of a mile south of Keene. Toward upper right, a large idiomorphic phenocryst of olivine with a thin magnetite or ilmenite rim and much decomposed to chlorite. On left, a large idiomorphic phenocryst of augite with zonal structure. Dark laths, biotite; black specks, magnetite or ilmenite; white material of matrix, plagioclase. Ordinary light. Magnified 23 diameters.

Lower right figure. Part of slice of gabbro from southern side of stock, 2½ miles south-southeast of Upper Jay. Toward top, two large rounded grains of olivine (with black streaks of secondary magnetite) surrounded by successive rims of granulated hypersthene, plagioclase, and garnet. Dark patches, hornblende. Part of large labradorite crystal at bottom. Ordinary light. Magnified 23 diameters.

cut all the other types of Adirondack rocks as narrow bands of slight areal extent. They are wholly nonmetamorphosed.

The fresh rock is dark bluish gray and generally fine grained, though a few of the larger dikes are medium grained toward the middle. Many of the dikes are distinctly finer grained toward their margins. A glassy groundmass occurs in a few cases. Many of the rocks contain small phenocrysts of augite or olivine, or both, and a few contain phenocrysts of plagioclase feldspar. A good diabasic texture is often clearly discernible with the naked eye in the relatively coarser grained rocks, and with the microscope in the finer grained ones, though some of the dikes apparently fail altogether to exhibit this texture.

In width most of the dikes range from less than an inch to 25 or 30 feet, and in length up to at least one-half of a mile. Most of the dikes show a general northeast-southwest strike, this being parallel to certain prominent structure (fracture) lines of the region. Some of the dikes strike nearly east-west, but not one was

Table 6 Thin sections of diabase

Slide no.	Field no.	Labradorite	Augite	Olivine	Biotite	Chlorite	Magnetite or ilmenite	Pyrite	Calcite	Glassy groundmass	Apatite
61	7 g 3	68	......	1	4	......	7	....	20	......	....
62	17 j 6	60	20	5	3	7	4	....	1	....	....
63	10 m 1	60	5	....	....	....	5	....	....	30	....
64	5 f 1	58	21	1	3	7	4	....	6	......	....
65	2 k 14	65	15	....	16	......	3½	little	....	....	little
66	1 k 2	30	40	4	20	......	6	....	....	....	....

No. 61, dike no. 33, High fall of West Branch Ausable river; no. 62, dike no. 48, 1½ miles southeast of Fremont hill; no. 63, dike no. 24, quarry at southern base of Hamlin mountain; no. 64, dike no. 5, one-half of a mile south-southwest of Owen pond; no. 65, dike no. 14, 1 mile north-northwest of Keene; no. 66, dike no. 9, one-half of a mile south of Keene in the gorge.

observed to strike northwest-southeast. Many of the intrusions quite certainly took place along zones of faulting of excessive jointing, but in some such cases, at least, renewed earth movements occurred after the intrusion of dike material because the dike rocks themselves, in such cases, are either brecciated or excessively jointed.

As seen in table 6, the chief minerals are labradorite and augite.

Special descriptions. No. 65 of table 6 is very typical of a medium-grained diabase without olivine from a dike 30 feet wide with fine-grained margins. The diabasic texture is plainly visible to the naked eye. Under the microscope the labradorite is seen to be in distinct laths, the biotite pale yellow to deep brown, and the augite pale brown with good cleavages. This rock is lighter gray than the usual diabase of the quadrangle.

In the southern part of the gorge of the river one-half of a mile south of Keene, a dike (no. 9) fully 5 feet wide cuts the mixture of granite and anorthosite. It stands in a vertical position, is traceable for fully 100 yards, and shows a fairly good columnar structure. The rock is really an olivine basalt porphyry. It is represented by no. 66 of table 6. Two generations of crystals are evident, all of the olivine and some of the augite belonging to an earlier period of crystallization, these two minerals clearly standing out as phenocrysts (black and pale yellowish green respectively) up to nearly a centimeter across. The groundmass is very fine grained, dull black, and without a diabasic texture. Under the microscope the olivine is colorless with crystal boundaries fairly well defined, and it shows some alteration to serpentine and hematite along the fractures. In thin section the augite is pale brown, mostly as rather idiomorphic crystals with good cleavages, and often with excellent zonal structures. The biotite is in the form of slender prisms with light to dark-brown pleochroism. The biotite evidently crystallized before the feldspar because the latter fills spaces between the biotite crystals. Much of the labradorite is in the form of small lath-shaped crystals.

In the gorge of West Branch Ausable river at High fall, there are several dikes (probably branches of a single large one) sharply cutting the granite parallel to its jointing. They are traceable for fully 100 yards in the walls of the gorge, the largest dike being about 5 feet wide. Just above High fall one of the dikes is brecciated. No. 61 of table 6 gives its mineral content. The rock under the microscope, is seen to be badly decomposed, which accounts for the large amount of secondary calcite.

On top of the ridge 1 mile east of Upper Jay there are seven or eight short dikes from 1 inch to 1 foot wide and roughly parallel, as indicated on the map. The largest is exposed for 75 feet. The middle ones are slightly faulted in a number of places.

A dike 4 or 5 feet wide is beautifully exposed at the lower end of The Flume where it cuts the Whiteface anorthosite vertically. It contains some inclusions of the anorthosite.

About one-half of a mile northeast of the summit of Catamount mountain, a diabase dike 3½ feet wide sharply cuts the largest gabbro-diorite dike obliquely and the granite parallel to its foliation. A few rods farther east there are five dikes, none over a few feet wide, and roughly parallel.

Near the summit of Catamount, a dike (no. 52) 6 feet wide may be clearly seen cutting the granite for several hundred feet. This may be a continuation of the large dike (no. 51) one-half of a mile to the northeast.

On the mountain top 1½ miles northeast of Catamount summit, there are several dikes from 2 to 6 feet wide, nearly parallel, and close together.

Dikes nos. 13 and 53, each about a foot wide, sharply cut gabbro stocks.

Dikes nos. 3, 30 and 35 show various branches or tongues extending into the country rocks. No. 3 is in contact with a pegmatite dike, and it is considerably brecciated due to faulting.

Dike no. 55, one-half of a mile north of Franklin Falls, is 2 feet wide. It contains fresh labradorite crystals as phenocrysts up to an inch long with very evident twinning bands.

Very instructive dikes may be seen at locality no. 28 where several dikes (one 10 feet wide) sharply cut Whiteface anorthosite. There were very plainly two injections of diabase magma here. The earlier injected mass was the larger, and it solidified into a dark bluish gray rock with a very fine-grained diabasic texture. The second injected masses are only a few inches wide, in sharp contact with the first; black and almost glassy with very small phenocrysts of labradorite whose long axes are approximately parallel thus causing this second intrusive to have a fairly good flow-structure. A similar combination of diabase cutting diabase was observed in a glacial boulder 1 mile southeast of Wilmington.

Dike no. 42 (see no. 63 of table 6) is only 4 inches wide, but it exhibits a very fine diabasic texture in the middle portion, and black glass at the margins.

At locality no. 18 several dikes from 5 inches to over 5 feet wide are close together and sharply cut Grenville quartzite.

In the old limestone quarry at dike locality no. 16, a good diabase dike with several small branches sharply cuts the limestone.

The Rocks of Catamount Mountain

A remarkable assemblage of rocks occurs within an area of less than 1 square mile, including the summit and southern base of

Catamount. Fully fourteen kinds of rocks are represented, most of them having been formed at different times. Oldest of all are the Grenville hornblende gneiss and crystalline limestone well shown in, and just west of, the quarry at the base of the mountain. In contact with this Grenville gneiss there are good outcrops of typical Whiteface anorthosite. On the southeastern slope of the mountain, syenite grades into granitic syenite, and this, in turn, into coarse granite. A narrow band of Keene gneiss, formed by assimilation of anorthosite by the granite magma, lies between the granite and anorthosite near the southern base of the mountain. Numerous small aplite dikes cut the granite parallel to the foliation toward the top of the mountain. In the vicinity of the aplite dikes, quartz veins lie across the foliation of the granite. Dikes of gabbro-diorite cut the granite roughly parallel to its foliation at and near the summit, and one-half of a mile to the northeast. A small stock of typical gabbro cuts anorthosite, Keene gneiss and granite near the base of the mountain. A diabase dike 6 feet wide sharply cuts the granite just south of the summit. A diabase dike and a small pegmatite dike cut obliquely across the larger of the gabbro-diorite dikes one-half of a mile northeast of the summit. Glacial deposits are extensively developed around the foot of the mountain.

STRUCTURAL GEOLOGY

Tilting and Folding of the Grenville Series

It has been generally assumed that the Adirondack Grenville strata have been severely compressed and folded as well as thoroughly metamorphosed and foliated by the compression. Recently, however, the writer has presented strong evidence[1] that the Grenville strata have neither been highly folded nor severely compressed, while many broad belts of Grenville are known to be practically undisturbed or only very moderately folded, and many masses, large and small, are merely tilted or domed at various angles. Very locally the strata are sometimes contorted. Parallelism of Grenville and syenite-granite rock belts is common with a general tendency toward northeast-southwest strike, but there are so many notable exceptions (some, for example, in the Lake Placid quadrangle) that any generalization, regarding such a strike of the rock belts as due to severe lateral compression, is of little significance.

[1] Jour. Geol., 24:588–96. 1916.

W. J. Miller, photo, 1916

Catamount mountain, looking northeast from West Kilns. The mountain (altitude 3168 feet) rises fully 1500 feet above the immediately surrounding country. The rock of the mountain is mostly coarse pinkish gray granite.

The structural relations of the Grenville strata are best explained as having been the result of slow, irregular upwelling of the more or less plastic magmas, probably under very moderate compression, whereby the strata, previously deformed very little or none at all, were broken up, tilted, and lifted or domed. The stratification surfaces of the Grenville were thus swung into general parallelism with the slow-moving magmatic currents. According to this view, individual large blocks or belts of Grenville strata, or several such blocks or belts separated by intrusive masses, with strike of intrusive masses parallel to the Grenville stratification, would be expected to show monoclinal dips; some Grenville masses were shifted around in the irregularly rising magmas so as to show various strikes according to the directions of movement of the magmas, and hence would not be expected to exhibit monoclinal dips; some bodies of Grenville were merely domed over bodies of rising magma and would therefore exhibit more or less quaquaversal strikes and dips; while still other masses of strata were probably bent or even considerably folded into synclines by being caught between bodies of magma upwelling at about the same rate. Most of these phenomena are illustrated within the Lake Placid quadrangle.

Foliation

General statements. All the Precambrian rocks of the quadrangle, except the diabase and much (or all) of the pegmatite, are more or less foliated. Large portions of the Marcy anorthosite are commonly practically devoid of foliation. Locally, some of the other intrusives exhibit little or no foliation. The degree of foliation often varies notably even within very short distances.

On the accompanying geologic map there are recorded representative strikes and dips of foliation selected from many field observations. There is a strong tendency for the strike to range from north-south to northeast-southwest, but many important exceptions occur. Sharp variations in strike occur in some relatively small areas, as, for example, at the southern end of Wilmington mountain. The direction and amount of dip also vary greatly, often within very short distances. High angles of dip are quite the rule. In many ledges the amount of dip can not be satisfactorily determined.

Foliation of the Grenville. Though the Grenville strata are always highly crystalline, they are, nevertheless, usually only moderately foliated. Stratification of the series is remarkably well

preserved. Parallelism of Grenville foliation and stratification appears to be universal. The Grenville has, for a long time, been regarded as essentially a result of severe regional compression after the great igneous intrusions had taken place. Recently, however, the writer has seriously questioned this view.[1]

If the Grenville and accompanying great intrusives had been subjected to compression severe enough to develop the foliation, is it not remarkable that the stratification surfaces have never been obliterated and cleavage developed instead, and also that stratification and foliation are always parallel? Also, unless we assume intense isoclinal folding, so that mineral elongation could everywhere have taken place essentially at right angles to the direction of lateral pressure, the parallelism of stratification and foliation can not be accounted for by crystallization under severe lateral pressure. But the Grenville strata were never highly folded. We are thus forced to the only alternative conclusion, namely, that the Grenville foliation was developed during the crystallization of essentially horizontal strata under a heavy load of overlying material. or, in other words, under conditions of static metamorphism. Those minerals which cause the foliation were elongated during crystallization under the heavy load of overlying material. According to this view, the parallelism of foliation and stratification is precisely what would be expected. This also explains the important fact that the Grenville rocks are notably less foliated and granulated than the great intrusives, particularly the syenite-granite series.

Foliation of the anorthosite and syenite-granite series.[2] By far most of the great intrusive rocks exhibit more or less well-developed foliation, ranging from very faintly gneissoid to very distinctly gneissoid, the structure usually being accentuated by the roughly parallel arrangement of the dark-colored minerals. Some masses, particularly of the Marcy anorthosite, are practically devoid of foliation. Granulation of minerals, especially feldspar, is common, the more highly foliated rocks generally being most granulated. The writer considers these intrusives to be so-called "primary gneisses" whose foliation was developed as a sort of magmatic flow-structure under moderate compression rather than by severe lateral pressure brought to bear upon them after the cooling of the magmas.

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[1] Jour. Geol., 24:596–600. 1916.
[2] For a rather full treatment of this subject, see the writer's paper in Jour. Geol., 24:600–16. 1916.

A brief summary of the writer's views may be stated as follows. During the processes of intrusion, which were long continued, the great magmatic masses were under only enough lateral pressure to control the general strike of the uprising magmas with consequent tendency toward parallel arrangement of intrusives and invaded Grenville masses; the foliation is essentially a flow-structure produced by magmatic currents under moderate pressure during the intrusions; the sharp variations of strike on large and small scales, and rapid variations in degree of foliation, are essentially the result of varying magmatic currents under differentiated pressure, principally during a late stage of magma consolidation; the almost universal, but varied, granulation of these rocks was produced mostly by movements in the partially solidified magma, and possibly to some extent by moderate pressure after complete consolidation; and the mineral flattening or elongation was caused by crystallization under differential pressure in the cooling magma. It would seem, therefore, that the general absence of foliation from so much of the Marcy anorthosite is best explained as the result of much more uniform intrusion of this single great body which was probably a stiffer or less fluid magma and which is less involved with Grenville masses, or, in other words, to much less forced differential flowage.

Foliation of the gabbro and gabbro-diorite. As already stated, the interior portions of most of the gabbro bodies are nonfoliated and they possess a diabasic texture, while the outer portions are highly foliated rocks, often true amphibolites. In many places the degree of foliation varies considerably within single stocks. More or less granulation is very common. This foliation and granulation have been quite generally regarded as secondary features produced by severe regional compression. But it is very difficult to imagine a process of development of foliation, which boxes the compass around the borders of the gabbro masses, by regional compression. Such foliation often of course strikes directly across the foliation of the older adjacent rocks. If due essentially to regional compression of the solidified gabbro, should not the foliation everywhere strike at least approximately at right angles to the direction of application of the pressure? Also how are such notable variations in foliation and granulation to be explained?

According to the writer's view, the foliation and granulation of the gabbro stocks are largely, if not wholly, primary features due to movements in the magma before final consolidation. Considerable pressures must have obtained within the stock chambers while

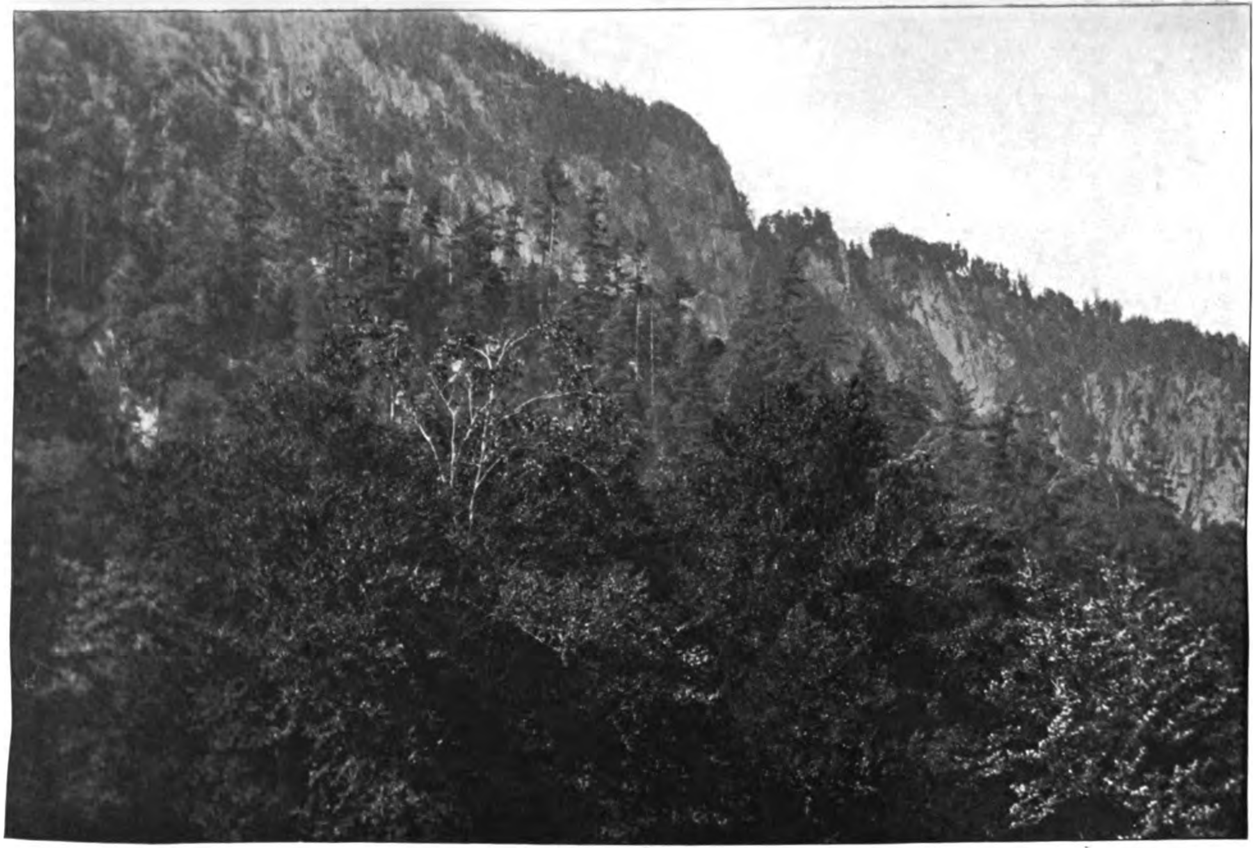
the magmas were being intruded under deep-seated conditions. Such pressure against the country rock, combined with the usual development of differential flowage, particularly in the magmatic borders, would readily account for the peripheral foliated zones which were produced, no doubt, during a late stage of magma consolidation. But the conditions for magmatic pressure and flowage must often have varied considerably, and thus the local variations in degree of foliation and granulation are accounted for.

The gabbro-diorite dikes are also more or less foliated, their borders particularly so. As in the gabbro stocks, so here, the foliation is considered to have been due to differential magmatic flowage under moderate pressure during a late stage of magma consolidation. In these dikes, however, the foliation was developed parallel to the strike of the dikes because cross-sections of the magma chambers were long and narrow rather than rounded or elliptical as in the gabbro stocks.

Faults

General features. Faults are neither so numerous nor so prominently developed as is usually the case in the eastern and southeastern Adirondack region. Within the Lake Placid quadrangle the faults are not sharply defined earth-fractures, but rather they are zones of excessive jointing in which more or less crushing and faulting of the rocks have taken place. These broken-rock zones are relatively straight for considerable distances, in some cases for some miles. It seems clear that such alignments of crushed-rock zones are due primarily to faulting, probably multiple faulting. The width of the fault zones is commonly from 25 to 100 feet or more. Most of them strike from northeast-southwest to north-south as usual in the eastern half of the Adirondack area. Because the rocks are broken up into numerous small blocks, the crushed zones form belts of weakness along which valleys (sometimes deep and narrow) have been developed. Little or no positive evidence regarding the positions of upthrow and downthrow sides could be obtained.

Wilmington notch fault. This is the finest example of a shattered-rock zone definitely known within the quadrangle. Its length, as indicated on the geologic map, is about 5 miles. The deep, narrow Wilmington notch, the gorge at High fall, and the gorge at The Flume, all owe their existence to rapid erosion along this prominent zone of weakness. In preglacial time the river did not



W. J. Miller, photo, 1916

Precipitous walls of the Wilmington notch which rise fully 1000 feet above the river on the west side. The camera was pointed upward at a high angle. The rock is syenite which shows a crude columnar structure due to excessive jointing in a fault zone.

flow through this deep, narrow valley, the site of the present Wilmington notch having then been a division of drainage or col which has been cut through by the West Branch Ausable river, the latter having taken this course as a result of the glaciation of the region (see chapter on the pleistocene geology). In fact the position of the whole valley of the river between Mt Whiteface and the Sentinel range has been primarily determined by the presence of the great zone of weakness in the rocks.

In the bed of the river three-fourths of a mile west-southwest of Owen pond, there is a big ledge of crushed rocks, especially pegmatite and diabase, which are distinctly brecciated. Some fragments of diabase have been mingled with the pegmatite. This zone strikes N 20° E. Along the river within the granite area in the notch, the rock is badly broken up in a wide zone parallel to the stream. Just northeast of this along the river, the Grenville gneiss is faulted with slickensides visible.

At High fall the granite of the gorge is highly jointed, the joint surfaces being from one to several feet apart, forming a zone of weakness which has determined the stream course. The joints strike N 40° E and dip 65° E. Slickensided joint faces are common. Just above High fall a diabase dike in the stream bed is brecciated, and close by is a distinctly slickensided scarp 4 feet high.

At the so-called Little High fall, about one-half of a mile below High fall, there is a very prominent crushed zone as wide as the river bed with a strike N 30° E.

In the river bed about half way between High fall and The Flume, there are two well-developed crushed-rock, or highly jointed, zones with strike parallel to the river. In The Flume the rock is considerably jointed, but just above the bridge there is an excessively jointed zone parallel to the course of the stream. Evidently the gorge development here has been greatly aided by the rock structure.

Faults in the town of Keene. At the southern end of the gorge one-half of a mile south of Keene, the rocks are badly broken up and somewhat slickensided, indicating a prominent crushed-rock zone here with strike about east-northeast by west-southwest. By the roadside at the edge of the gorge, this fault zone is well exposed (see plate 21). The topography strongly suggests the continuation of this fault zone some distance northeastward as indicated on the map, but this is not verified by actual outcrops.

By the roadside nearly 2 miles north of Keene, the Whiteface anorthosite and Grenville mixed rocks are much broken up, some-

what slickensided, and considerably weathered. The strike of this crushed-rock zone is about north-south, but no other crushed rocks are exposed along this fault zone as mapped.

The Grenville gneiss in the small gorge of Styles brook is excessively jointed, forming a zone of weakness with strike east-west or parallel to the stream course (see map). Tracing this zone eastward was impossible because of lack of outcrops.

A fault zone of weakness has almost certainly determined the position of the deep, narrow valley between Pitchoff mountain and the southern end of the Sentinel range as indicated on the geologic map, though actual exposures of faulted or excessively jointed rocks are lacking at the critical localities.

Other faults. Several nearly vertical faulted joints pass across the small quarry at the southern end of Lake Placid. They strike N 30° E and probably represent a fault zone which extends through the long, narrow, eastern portion of Lake Placid, but, if so, it is everywhere under water. The long, narrow, western side of the lake basin also strongly suggests its origin along a fault zone of weakness, but positive evidence is lacking.

The group of diabase dikes about a mile east-northeast of Upper Jay are slightly faulted in a number of places.

Possibly a fault zone has determined the position of the prominent valley which separates Catamount and Wilmington mountains, but positive evidence is entirely lacking because of heavy drift covering, and it is possible that simple removal of a large mass of relatively weak Grenville rock by erosion has caused this valley.

The notch between Mt Whiteface and St Armand mountain suggests a development along a north-south fault zone, but outcrops in the notch do not appear to have been faulted.

Plate 21

W. J. Miller, photo, 1915

Crushed-rock zone due to faulting by the road, one-half a mile south of Keene

PLEISTOCENE GEOLOGY

BY HAROLD L. ALLING

INTRODUCTION

In the detailed mapping of the quadrangles in the Adirondack region more attention has usually been given to the crystalline rocks than to the Pleistocene geology. The glacial phenomena, however, are clearly discernible and promise to add materially to the knowledge of the Pleistocene history of the State of New York when fully worked out. Besides the usual types of glacial deposits the Lake Placid quadrangle exhibits deltas, terraces and shore-line features of a succession of extinct glacial lakes whose history can be traced with a fair degree of accuracy. Unfortunately for concise description, the lakes were not confined entirely to the quadrangle so it is necessary in many cases to examine adjacent topographic sheets in order to appreciate the extent and history of each during its initiation, life and extinction. Nevertheless only those lakes which formerly covered some portion of the Lake Placid quadrangle will be described.

Although positive evidence of multiple glaciation in the Adirondacks is not, as yet, forthcoming, Prewisconsin glaciation in Pennsylvania, New Jersey and on Long Island[1] has been established so as to lead us to the conclusion that this area has been subjected to continental ice bodies more than once. In some of the stream valleys the depth of the drift is enormous and a difference in the character of different levels can often be detected. If evidence is to be found of Prewisconsin ice action in the Adirondacks, it is in such deposits.

But as the surface deposits are chiefly due to the last or Laurentian lobe of the Wisconsin ice, we shall confine ourselves to its effects.

Wisconsin Glaciation

Without much doubt the entire Adirondack region was completely buried by the ice, which has been estimated to have been 9000 to 12,000 feet in altitude over the central Adirondacks.[2] To this enormous load upon the land surface is attributed the well-observed phenomenon of deformation, to which we will return later.

[1] Fairchild, H. L. Bul. Geol. Soc. Amer., 24:134.
[2] Fairchild, H. L. Geol. Soc. Am. Bul., 24:136. After Shackleton.

Movement

Seventeen occurrences of glacial striae have been noted in the quadrangle; they are especially numerous beside the highways in the valley of the East branch of the Ausable river. The majority of them have been observed by Doctor Miller, who has indicated them upon the accompanying map. The striae in the valleys were made by the waning stages of the glacial lobes, for their direction has been influenced very largely by the topography of the country. The more general direction of the ice flow would be shown by striae on the mountain summits, but their records have been destroyed by weathering agencies. Nevertheless it can be stated that the ice that covered the quadrangle flowed southward with a slight deviation to the west.

Table of Glacial Striae

STRIAE	TOWNSHIP	LOCATION	OBSERVER
S 45° W	Franklin	$\frac{1}{4}$ mile north of Franklin Falls	W. J. Miller
S 45° W	Franklin	$\frac{3}{4}$ mile northeast of Franklin Falls	W. J. Miller
S 77° W	Black Brook	1 mile northwest of East Kilns	H. L. Alling
S 40° W	Wilmington	2 miles east of Wilmington	W. J. Miller
S 62° W	Wilmington	3 miles southeast of Wilmington	J. F. Kemp
S 12° W	Jay	Southeast of Upper Jay	J. F. Kemp
Due S.	Jay	$\frac{3}{4}$ mile south of Upper Jay	W. J. Miller
S 10° E	Jay	2 miles southwest of Upper Jay	W. J. Miller
S 15° E	Keene	$2\frac{1}{4}$ miles north of Keene	W. J. Miller
Due S.	Keene	$1\frac{3}{4}$ miles north of Keene	W. J. Miller
Due S.	Keene	$1\frac{1}{2}$ miles north of Keene	W. J. Miller
S 10° E	Keene	$1\frac{1}{4}$ miles north of Keene	H. L. Alling
Due S.	Keene	$1\frac{1}{2}$ miles north of Keene	H. L. Alling
Due S.	Keene	$1\frac{1}{4}$ miles north northwest of Keene	W. J. Miller
S 25° E	Keene	$1\frac{3}{4}$ miles northeast of Keene	W. J. Miller
S 10° E	Keene	$\frac{1}{4}$ mile southwest of Keene	W. J. Miller

Erosional Work

The residual soil resulting from weathering during interglacial periods was completely removed by the ice, the mountains smoothed and their contours subdued. The extent of ice action is recorded in the comparatively fresh condition of the rocks on exposed ledges, as is shown on the bare slopes of Pitchoff mountain, on the southern edge of the map.

The many amphitheaters and little rocky pockets on the mountainsides are due, in all probability, to the erosive action of the ice. These cirques have been attributed to the combined work of the continental ice bodies and to local glaciers.[1] They are visible on

[1] Ogilvie, I. H. Glacial Phenomena in the Adirondacks, Jour. Geol., 10:406. 1902.

Johnson, D. W. Date of Local Glaciation in the White, Adirondack, and Catskill Mountains, Geol. Soc. Amer. Bul. 28:543–52. 1917.

the slopes of Whiteface, Sentinel[1] and especially Esther mountain. The origin of rocky pockets, now occupied by ponds, on the southwestern slopes of some of the mountains is not clearly understood, but plucking action of the ice may be regarded as a contributing cause.

In pushing through the major fault-line valleys, such as the Pitchoff "pass," the Wilmington Notch, and also the Middle Kilns valley, the ice carried with it the talus material that had accumulated during interglacial periods, freshened out the valley walls and left U-shaped valleys, blocking both ends with crescent-shaped moraines as it retreated.

The occurrence of glacial boulders is quite common, some of which appear to have been transported from great distances while others can be traced to parent ledges in the neighborhood. Rounded boulders of Potsdam quartzite have been noted all over the quadrangle. Large irregular slabs of Potsdam sandstone and quartzite are encountered in some of the brook valleys where the drift is abnormally thick. To the north of the road running from Upper Jay to Wilmington, some 2 miles directly south of the latter, irregular nonglaciated flagstones were encountered in such numbers as strongly to suggest that a ledge of the Potsdam existed here before the ice invasion broke it up. Similar occurrences in the Elizabethtown[2] and Mt Marcy quadrangles,[3] together with outliers,[4] point to the conclusion that the Adirondacks were submerged in the Potsdam sea to a much greater extent than was formerly considered to be the case.

Moraines

There is but little true morainal material to be found in the Lake Placid quadrangle, for most of it has been modified by water;[5] the movement of the ice during the maximum advance having evidently been too vigorous for deposition and the material that was deposited as the ice retreated having been sorted by the waters of the glacial lakes.

The recessional moraines appear to be largely confined to the fault-line valleys, being formed by the ice-tongues as they withdrew from the narrow defiles. At the southern ends, in the broad

[1] Kemp, J. F. The Geology of the Lake Placid Region, N. Y. State Mus. Bul. 21, p. 21.

[2] Rudemann, Rudolf, N. Y. State Mus. Bul. 138, p. 62.

[3] Alling, H. L., Bul. Geol. Soc. Amer. 27:650.

[4] Miller, W. J., N. Y. State Mus. Bul. 182, p. 44.

[5] Cushing, H. P., N. Y. State Mus. Bul. 115, p. 496.
Ogilvie, I. H., Jour. Geol., 10:406.

valleys, the rate of retreat was slow and moraines were formed; but in the narrow valleys the melting of an equal amount of ice would produce a much more rapid recession, giving but little opportunity for the deposition of material. Again at the northeastern ends of the passes the ice-tongues paused long enough to deposit another series of moraines.

The damming of such valleys by recessional moraines has resulted in the Cascade lakes, located in the Mt Marcy sheet; and in Silver lake and Taylor pond on the northern edge of the Lake Placid quadrangle. A very striking example of morainal damming is Lake Placid, formed by the blockading of two parallel (fault-line?) valleys which have been joined by valleys, producing the islands, thus forming a ladder-shaped body of water. In a depression in the dam Mirror lake now lies. Just south of Mirror lake Doctor Miller found, beside the road, an exposure 20 feet thick, which showed glacial till with large boulders in the upper half resting upon distinctly stratified sands.[1] The writer would infer that during slight variations in the advance and retreat of the ice lobe, glacial debris was deposited on top of a glacial lake bottom (see page 83. Glacial Lake Upper Newman). A similar phenomenon is known in the Cobb's hill kame-moraine at Rochester, N. Y.

The preglacial drainage has been modified by glacial material of one kind or another in several localities. A good example was found south of the town of Keene in the East branch of the Ausable river. In this comparatively broad valley on the northern edge of the Mt Marcy sheet we note an unnamed hill, around the two sides of which the two highways leading to Keene Valley circle. To the west of this hill the present river rushes between steep walls of syenite and mixed rocks (southern edge of the Lake Placid quadrangle), experiencing rapids and falls. It is clearly a postglacial channel and is one of the beauty spots in the quadrangle. On the other side of this hill the preglacial channel is plainly perceptible, although now blocked by sands of a lateral delta.[2]

Local Moraines; Local Glaciation

The writer's work in the central Adirondacks would lead him to suspect that local glaciers existed on the slopes of the higher mountains. This conclusion has been reached through the study of

[1] Miller, W. J., Personal communication, Jan. 17, 1917.

[2] Alling, H. L., Glacial Geology of the Mt Marcy Quadrangle, in The Geology of the Mt Marcy Quadrangle, Kemp, J. F., *in preparation;* N. Y. State Mus. Bul.

D W. Johnson, photo, 1916

Looking down into the cirque on the northeast slope of Esther mountain. Looking north from an elevation of about 3800 feet.

Plate 23

D W. Johnson, photo, 1916

Local moraine in cirque on the northeast slope of Esther mountain. Altitude about 3000 feet. Three-fourths of a mile long.

lateral moraines, usually modified and dissected by streams in the brook valleys, often of perplexing character, but suggesting local origin; and through the presence of poorly developed cirques, on the mountain slopes; and hanging tributary valleys. In 1916 the writer, under the leadership of D. W. Johnson, found in the incipient cirque on the eastern slope of Esther mountain (a portion of the Whiteface massif) a narrow ridge of debris at an altitude of about 3000 feet, some three-fourths of a mile in length. Its form is that of a glacial moraine rather than that of a landslide. This cirque valley slopes northeast, which offered a favorable opportunity for the continental ice to force a tongue into it and to deposit a recessional moraine; but this would have a crest declining southwest, while the moraine found has the opposite inclination. Furthermore the northeastern end points slightly toward the axis of the valley. The moraine is very well preserved and it is inconceivable that this ridge of unconsolidated material could have withstood the destructive forces of the ice sheet. We must, therefore, conclude that local glaciation took place *after* the withdrawal of the main ice body from the region.[1]

It is sometimes argued that if local glaciers occupied the cirque valleys, small terminal moraines should, in every case, be found at their lower extremities; their absence being taken as evidence for dating such action before the continental ice invasion, which caused their destruction. The studies of de Martonne in the Alps and the Carpathians show that in regions now undergoing Alpine glaciation, where the complications of continental ice bodies are absent, local moraines are seldom prominent features, for the glacial streams destroy them. Thus as a rule only one or two moraines are found in every ten cases examined.

It is reasonable to expect that local glaciation could not have been limited to the Catskill mountains (which is a region unlikely to support local glaciers) without the Adirondacks likewise experiencing it; hence, since local glaciation has been established there,[2] it lends weight to the above conclusion.

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[1] Johnson, D. W., Date of Local Glaciation in the White, Adirondack and Catskill Mountains. 29th Annual Meeting Geol. Soc. Amer., Bul. 28:545–52. 1917.

[2] Rich, John L., Notes on the Physiography and Glacial Geology of the Northern Catskill Mountains, Am. Jour. Sci., 39:154. Feb. 1915. Local Glaciation in the Catskill Mountains, Jour. Geol. 14:113-21. 1906. Local Glaciation in the Catskill Mountains. Geol. Soc. Amer. Bul. 28:133 (abstract) 1917.

Eskers are infrequent on this quadrangle, although a number have been located in the Mt Marcy, Ausable, Saranac and St Regis sheets. The writer has seen within the present limits no glacial deposits as undoubted eskers, but Doctor Miller considers to be such an east-west ridge some 200 yards long and 30 to 50 feet high, observed by him, one-half of a mile directly east of the cross roads at Keene.

Kames are likewise uncommon. In the vicinity of the southwestern end of the Middle Kilns valley a number of irregular hills are strongly suggestive of kame topography.

Outwash Plains

Outwash plains can generally be distinguished from deltas and glacial lake bottoms by ice blocks, kettle holes, and the lack of shoreline features. Frequently, however, in the field such distinctions are difficult, if not impossible, to make unless accompanied by other positive evidence. Some of the sand plains in the quadrangle are rather perplexing and their origin may be complicated, although it is believed that the majority of them were formed in connection with the glacial lakes described here.

Extinct Glacial Lakes

Conditions Favorable for Glacial Lakes in the Region. A number of important factors were favorable for the formation of several series of local glacial lakes in the east central Adirondacks, and some of these bodies of water existed in the area covered by this bulletin. Among the conditions we note: (1) northward-draining valleys, sloping toward and blocked by ice lobes; (2) the complete isolation of such valleys by mountain ranges; and (3) the presence of a huge ice ring that completely surrounded the highlands, impounding vast quantities of water. This area was situated close to the northeast rim of the ring. The large amount of available material for the formation of deltas, terraces and beaches, makes recognition possible. The cause of the great quantities of sand is discussed later on.

A number of glacial lakes in the quadrangle have been noted in the past by Taylor,[1] although he did not attempt to separate and correlate the different levels, and by Kemp who has noted[2] two or

[1] Taylor, F. B., Lake Adirondack, Amer. Geol., 19:392–96. June 1897.

[2] Kemp, J. F., Geology of the Lake Placid Region, New York State Mus. Bul. 21, p. 60.

three sets of deltas in the Keene valley. It has fallen to the writer to attack the problems of the glacial lakes of the east central Adirondacks, and to attempt to translate something of the wonderful history. In such pioneer work mistakes and faulty interpretations are apt to appear, for it is impossible to avoid errors.

In dealing with the glacial lakes the writer has, for convenience, classified them into three sections: (1) the western section, that is, the region around Lake Placid, to the west of the Wilmington notch; (2) the eastern section, or the Keene valley division in the valley of the East branch of the Ausable river; and (3) the Elizabethtown valley group. The last section does not come under discussion here.

Upper series: western section. As the ice sheet began to wane, the highest peaks of the Adirondacks were the first to be uncovered, playing the rôle of islands in a sea of ice.[1] Slowly these islands became larger, surrounded by a growing accumulation of water impounded by the ice. These waters found escape over the ice to the south and eventually passed to Susquehanna drainage. This process of melting was continued until entire mountain ranges were exposed.

The South Meadows lake. The highest definite level recognized by the writer in the Adirondacks, as shown by sand plains, terraces and beaches, is one ranging from 1940 to 2210 feet in altitude. When this level was first appreciated some hesitation was felt in describing it as glacial, for no shore-line features or outlets had been noted. It was considered as outwash plains formed by aggrading glacial streams that flowed from the melting ice, but as extended field work was undertaken these lake phenomena were discovered, *or strongly suspected,* and hence the true nature of the plains was established.

The best development of the glacial deposits of this lake is in the northwest corner of the Mt Marcy sheet in the South Meadows country; hence the name — South Meadows lake. As can be seen in figure 2, the writer conceives that it covered the southwest portion of the Lake Placid quadrangle and the corners of the adjacent sheets. The ice consisted of three lobes: one covered the greater portion of the Saranac sheet; the second lobe was fed through the narrow passes to the east and west of the Whiteface-Esther-Wilmington massif and covered the territory where Lake Placid

[1] Fairchild, H. L., N. Y. State Mus. Bul. 160, pl. 11.

now lies; the third and the most eastern lobe, here considered, completely filled the valley of the East branch of the Ausable river and Keene valley.

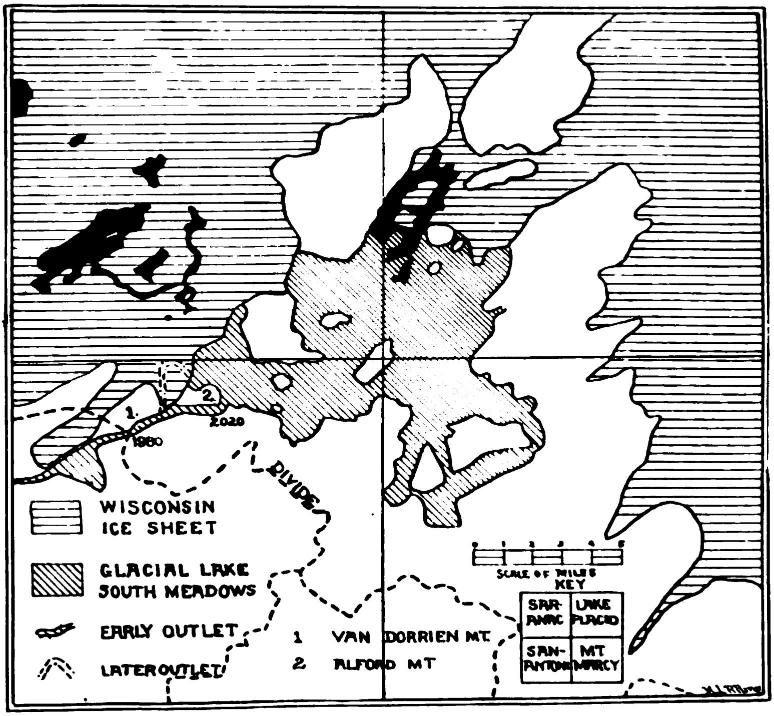


Fig. 2 The Glacial Lake succession in the Lake Placid quadrangle. Stage one.
The South Meadows lake, altitude 1940 to 2210 feet.

The South Meadows lake was of irregular shape, some 10 miles long and wide, containing a number of islands. Its outlet has not, as yet, been definitely established, but a very probable one is offered as follows. It begins at the swamp just south of Alford mountain in the Santanoni quadrangle, on the Essex-Franklin county boundary line (altitude 2105½ feet), and passes westward through the narrow pass (altitude 1980 feet) directly south of Van Dorrien mountain to Blueberry pond. Continuing westward into the Long Lake quadrangle, on the boundary between the two maps, it turns to the southwest and passes three-fourths of a mile south of Palmer brook. When within a mile of the Raquette river, the course turns directly south over Brueyer pond. This river course is a mere suggestion as actual field work has not been undertaken in the rugged

and inaccessible Santanoni quadrangle. Probably the waters flowing through this channel did not form a single river but consisted of a chain of lakes and ponds. Just where the ice control was located for each successive level is not known.

The glacial sands, gravels etc. form a filling in the South Meadows country that is estimated to be at least 300 feet thick. This matter will be referred to again in another connection.

A number of unmistakable beaches exist on the shoulders of the Sentinel range and on Scott's cobble, northern edge of the Mt Marcy sheet. The altitude of a series of them ranges from 2146 to 2209 feet.[1] These figures, in all probability, represent the water levels during the early stages of the lake. Sand plains with altitudes close to 1960 feet strongly suggest that the lake was undergoing constant lowering, perhaps as the small ice lobe 3 miles east of the highest peak of Ampersand mountain retreated and allowed escape through the channel of the East branch of Cold brook and then south, lowering the level to 1960 feet as set by the Van Dorrien pass mentioned above. (See figure 2 as indicated by the "later outlet.")

The fault-line valley containing the Cascade lakes (Mt Marcy quadrangle) was probably filled by morainal material and by a glacial lobe, preventing escape to the east; thus the outlet was to the west as suggested above.

Western portion of Upper Lake Newman. With the gradual retreat of the ice and its constant shifting of position, new and lower outlets were exposed. Succeeding the South Meadows lake, the western portion of Upper Lake Newman, as the writer proposed to call it,[2] was ushered in. As the remnants are rather indefinite in character and the range is considerable, 1800 to 1895 feet, the writer is not unmindful that stream filling forming an outwash plain from the glacier may be an alternative explanation; but in view of the fact that sand plains are found over a considerable area confined within definite limits of range of altitude, they are assumed to represent a series of lake bottoms formed by a lake whose level was experiencing periodic lowering due to the downcutting of the controlling spillways. These spillways may have been over the ice itself or a series of outlets which were over rock. Unfortunately, however, the outlets of the lake are not positively

[1] Determined by a surveying aneroid barometer and checked against a barograph, hence as accurate as this method permits.

[2] Alling, H. L., "Geology of the Lake Clear Region." N. Y. State Mus. Bul. 207, 208, p. 133.

known but in all probability the drainage was to the west, similar to that of the South Meadows lake.

This lake was even more extensive than the South Meadows lake if the writer's conception is correct. It covered the area now occupied by the southern end of Lake Placid, the western end of the Wilmington notch, and sent a four-fingered bay into the South Meadows country and flooded the southern edge of the Saranac quadrangle. The valley of the East branch of the Ausable river was occupied by an ice lobe, preventing any connection between the eastern and western portions of the Lake Placid quadrangle.

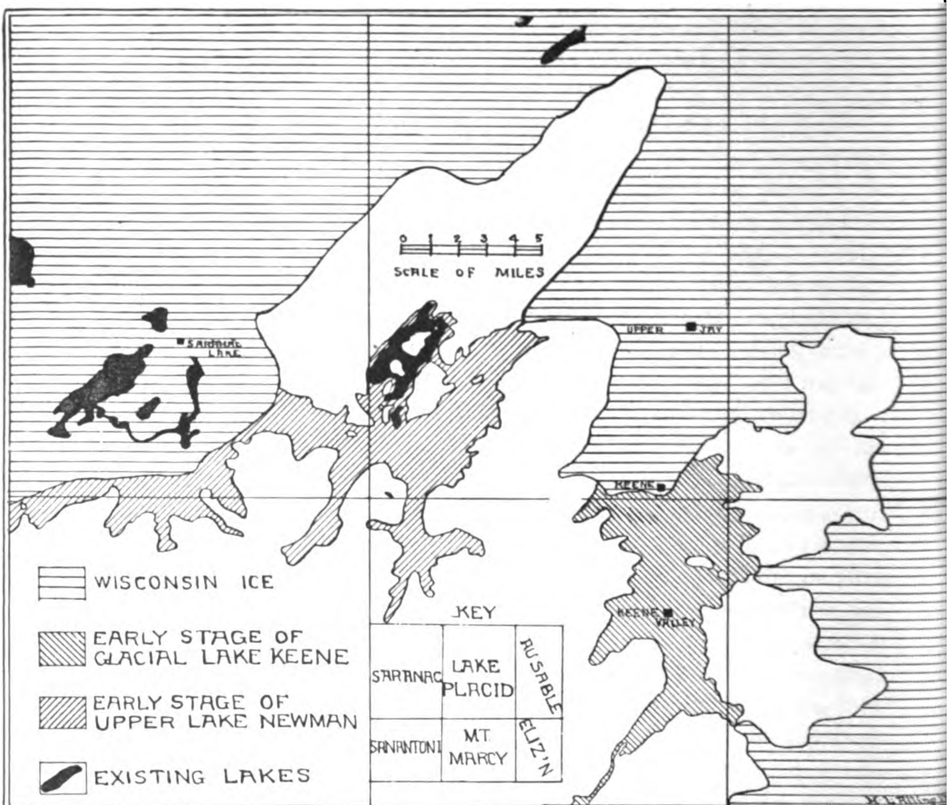


Fig. 3 The Glacial Lake succession in the Lake Placid quadrangle. Stage two.

The South Meadows lake was succeeded by the western section of Upper Lake Newman, altitude 1800 to 1895 feet. The ice lobe in the valley of the East branch of the Ausable river had retreated since stage one to allow the Keene lake to accumulate.

The best preserved terraces of the Upper Lake Newman were found in the extreme southwest corner of the quadrangle in the neighborhood of John Brown's grave and along the West branch of the Ausable river. The name of the lake is derived from the town of Newman, the terminus of the Delaware and Hudson Railroad, where well-preserved levels occur on the north, south and more especially at the point where the Lake Placid-Keene highway crosses the river. Here a striking view of them may be obtained.

As may be inferred from figure 3, the present theory is that a portion of the ice body that was responsible for the existence of Upper Lake Newman, was situated for a time near the southern edge of what is now Lake Placid, and it is believed that the morainal dam that later brought about Lake Placid was formed during this period. The ice experiencing minor advances and retreats produced the exposure above mentioned, showing drift on top of the stratified sands of Upper Lake Newman.

In the vicinity of John Brown's grave, well-preserved benches show a complete separation of Upper Newman from the succeeding lake, Lower Newman; the upper series ranging from 1800 to 1820 (one well-marked level at 1806.5 feet) while the lower group vary from 1740 to 1780 feet. The same difference in levels was found in the Saranac quadrangle one-half of a mile north of Harrietstown, where a corresponding group of benches occurs.[1]

Upper series: eastern section. *The Keene lake.* During the greater portion of the life of the western portion of Upper Lake Newman, the ice lobe in the valley of the East branch of the Ausable river was retreating northward and allowed a growing body of water to accumulate in the Keene valley. This body of water, named the Keene lake, left terraces high up on the valley walls, especially in the brook valleys where the present streams have bisected them. The sands on East hill at 2000 feet altitude, in the southeast corner of the Lake Placid map, were probably deposited at this time. The greater portion of the lake, however, filled Keene valley and thus was largely located within the confines of the Mt Marcy sheet.

The outlet is regarded to have been to the south through the double fault-line valley, in which the famous Ausable lakes are now located, into standing waters in the northern half of the Schroon lake sheet. The two passes to the east, namely, the Spruce hill

[1] Alling, H. L., "Geology of the Lake Clear Region. N. Y. State Mus. Bul. 207, 208, p. 133.

pass and the Chapel pond pass on the western edge of the Elizabethtown sheet, although much lower than the surface of the water, were effectively blocked by side ice lobes from the glacial tongue that occupied the Elizabethtown valley, preventing eastward escape.

It seems quite likely that as the lobe, which prevented northward escape of the Keene lake, gradually retreated, it at last uncovered the eastern end of the Wilmington notch which furnished connection with the western portion of the area, and then the waters in the valley of the East branch fell to the level of Upper Lake Newman.

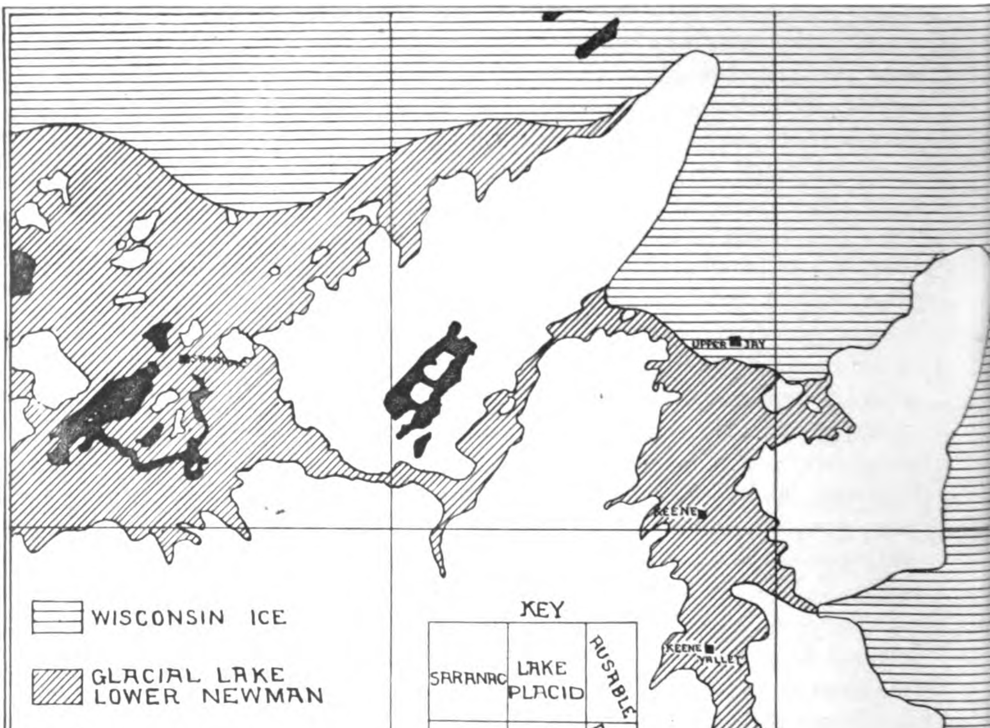


Fig. 4 The Glacial Lake succession in the Lake Placid quadrangle. Stage three.
The Keene lake was succeeded by the eastern section of Upper Lake Newman when the ice lobe in the valley of the Ausable river had retreated to uncover the Wilmington notch, allowing discharge to the west. Both eastern and western sections of Upper Lake Newman were succeeded by Lower Lake Newman, altitude 1740 to 1780 feet.

Eastern portion of Upper Lake Newman. The life of the eastern portion of Upper Lake Newman was probably relatively short compared with that of the western area, for the terraces are very indefinite and the separation of the benches into an upper and a lower series does not exist, or at least can not be demonstrated. Thus soon after the establishment of greater Upper Newman, the outlet was changed, perhaps rapidly deepened by the additional volume of water from the eastern section, so that the waters fell to the level of Lower Lake Newman.

Upper series: eastern and western sections. *Lower Lake Newman.* This lake was of still greater extent than any of the above-described bodies of water. Its northern, and especially the northwestern, extent and boundaries are still to be studied and worked out. Our present knowledge would lead us to conclude, however, that the valleys occupied by the West and East branches of the Ausable river were flooded, the connecting link between the two being the Wilmington notch. This is inferred by the fact that deltas and terraces at similar heights were found to the east and west of the Notch; how else could the waters of the two areas have been confluent? These waters thus flooded the area covered by Lake Placid and the greater portion of the Saranac quadrangle. As the ice barrier retreated the area around Franklin Falls was covered by the later stages of Lower Lake Newman. The outlet is assumed to have been west, although its location is at present unknown. It is possible, though exceedingly unlikely, that the Chapel pond pass may have been an outlet toward the close of this period, changing the drainage to the east.

The South Meadows, and the two Newman lakes, probably had outlets to the west; the Keene lake drained south; but the succeeding lake (or group of lakes) had drainage to the east.

Saranac glacial waters. The series of sand plains, terraces etc. that come under this head were recognized and described by H. P. Cushing,[1] in the Saranac region, in what is generally known as the "lake belt." These levels have such a wide range, 1450 to 1660 feet, that they must have been produced by a series of glacial lakes, or have been deposited by aggrading streams which no longer exist, or by a combination of both.

Doctor Cushing is of the opinion that "these sands were probably deposited as deltas in a large irregular, shallow, lake formed

[1] Cushing, H. P., Recent Geological Work in Franklin and St Lawrence Counties, N. Y., State Mus. Annual Rep't. 1900, p. r29.

back of the ice tongue which occupied the 'lake belt' during its slow retreat north, the material being furnished by the subglacial and englacial streams flowing into the lake at the ice margin."

As nearly two-thirds of the Saranac sheet exhibits terraces and sand plains of the higher levels, it was proposed that the name "Saranac glacial waters" be applied to the standing waters that built these levels, although the waters covered portions of the Lake Placid, Mt Marcy and Ausable quadrangles.

Extensive levels are preserved within the area in the brook valleys such as Clifford, Styles, Brown's and New Bridge brooks and to the east and west of the town of Wilmington.

The general character of the terraces is that of gently sloping plains on the mountain slopes without any prominent shore-line features. An exception to the last statement is a wave-cut cliff on the south side of the Styles Brook valley. The indefinite nature of nearly all the sand plains strongly impressed the writer and thus he was inclined to view them as having been formed by aggrading glacial streams, the remnants now existing being merely portions left undisturbed by the present streams. But field work revealed a remarkable series of outlets in the center of the Ausable quadrangle that furnish evidence for regarding them as glacial lake features.

Outlets. Here again we must depart from the confines of the Lake Placid quadrangle to understand the nature of these conspicuous levels. Although a detailed description of the outlets will not be given, a short summary of them is indispensable.[1]

Beginning on the southern slopes of Ellis mountain, in the township of Jay, a long glacial channel extends south for a distance of some 9 miles with a dozen side outlets to the east. The lake entrance to this channel was at the northern end, south of Ellis mountain. The controlling spillways were regulated by an ice lobe that lay to the east. Thus it is the writer's opinion that as the ice retreated it permitted escape first by the most southern side outlets which represents the outlet of the early stages of the Saranac glacial waters; while as the ice continued to retreat, lower spillways were opened farther north with a consequent lowering of the waters.

In several of these side-outlet channels "fossil" or dried-up falls and cataracts are found. The channels are very impressive

[1] For a fuller account, see Alling, H. L., The Glacial Lakes and Other Glacial Features of the Central Adirondacks, Bul. Geol. Soc. Amer., 27:658 and fig. 1.

and, together with the correlation of the elevations of the outlets and minor breaks in the sand plains, furnish positive evidence of the nature of these levels.

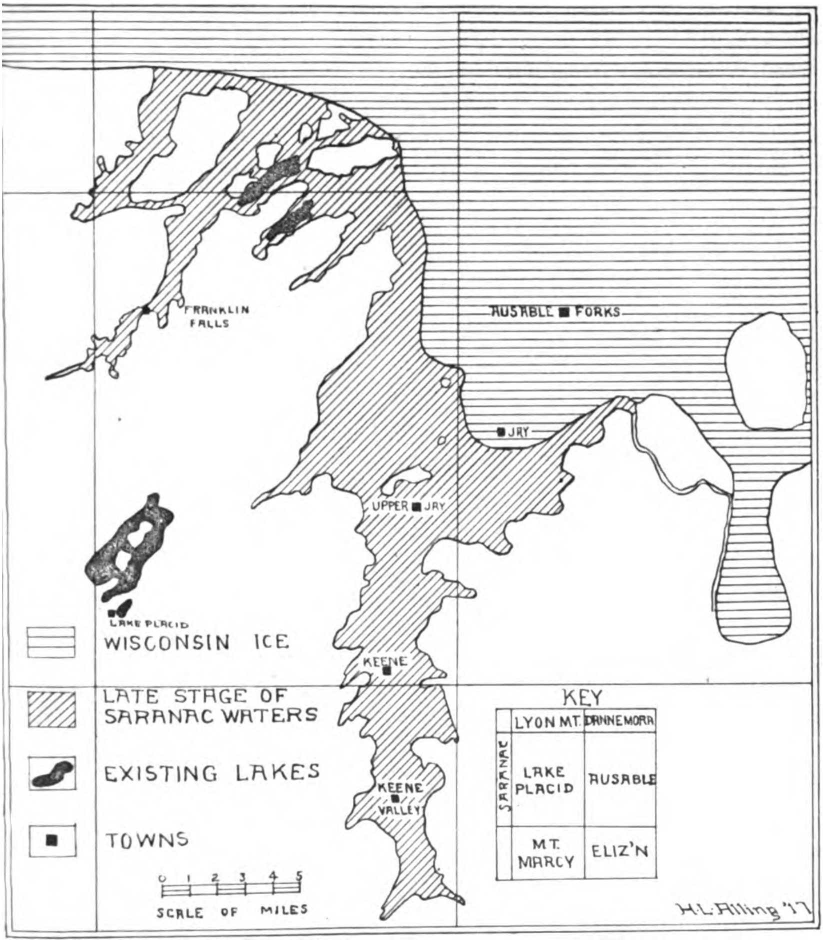


Fig. 5 The Glacial Lake succession in the Lake Placid quadrangle. Stage four.

With the opening of the glacial channels in the Ausable sheet the Lower Newman Lake was succeeded by the Saranac glacial waters, the late stage of which is indicated on the map. The altitude of this series of lakes range from 1440 to 1660 feet, although the level shown is that at 1500 feet.

There is a decided "gap" in the sand plains in the Saranac levels at about 1550 feet, and thus it would be proper to subdivide the lake into upper and lower phases, but as the lake had a succession

of outlets such a simple division is insufficient, so we shall regard the Saranac waters as a series of lakes. The chief cause for the indefiniteness of the levels and the lack of shore-line features must be attributed to the fact that the ice was the barrier in many cases. Many one-bank channels exist, showing that the spillways were constantly being lowered by the melting ice.

The lower stages of the Saranac waters were chiefly confined to the eastern section, as can be seen from figure 5.

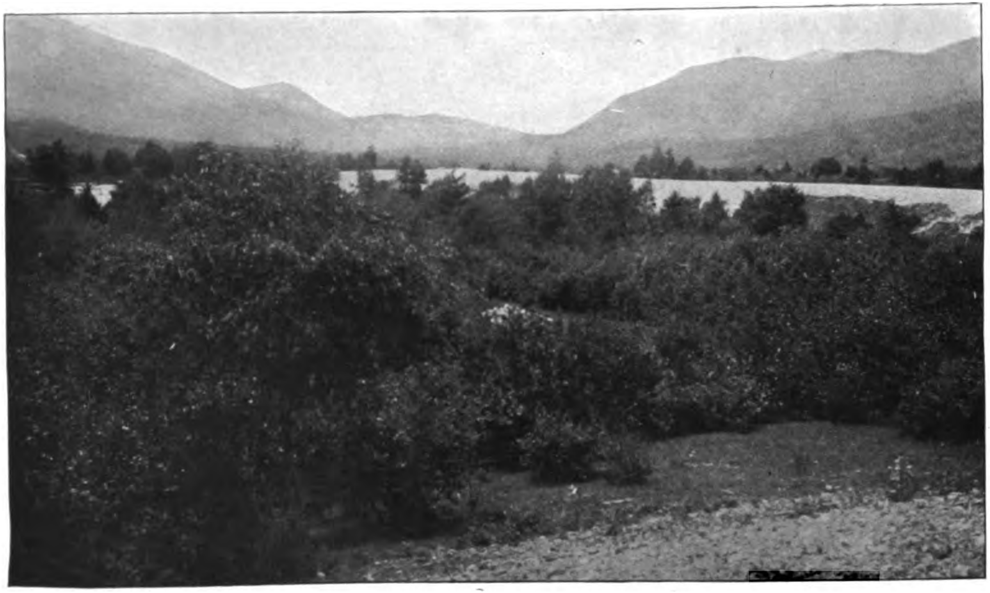
Eastern section. *St Huberts lake.* At a lower altitude than the Saranac water levels there are scattered over the area sloping terraces of indefinite character that remind the writer of the preceding plains. They are regarded as subordinate in interest to the preceding levels and to those which are described below. There is a small but finely developed terrace at the head of Keene valley at 1300 feet. This level surface is now used as a baseball diamond. Taking this as a starting point the other terraces seem to fit in with the general scheme, and hence there is a possibility of a lake level in the series that once flooded portions of the Lake Placid quadrangle. The most prominent remnant left of this level is on the northeast slopes of Owls Head now traversed by the Keene-Cascade highway. Its outlet was, without much doubt, through the gulf, south of Ellis and Black mountains in the Ausable sheet to the east, the spillways being controlled by one-bank channels which are beautifully shown on the southeast slopes of Black mountain.

Lower series: confined entirely to the eastern section. In descending from the higher lake levels to the lower ones, the character of the terraces changes from indefinite levels of considerable range to neat, clear-cut deltas, wave-cut cliffs and beaches confined within concise limits. No question can be raised as to the origin of many of them. They represent remains of true glacial lakes.

Wilmington lake. The history of the Wilmington lake is, perhaps, the best understood of all these local lakes. It was chiefly confined to the Lake Placid sheet, to the East branch of the Ausable river, and to the territory around the town of Wilmington; and stretches northward to Lower Jay. (See figure 6.)

The altitude is 1100 feet at the foot of Johns brook in Keene valley where a typical delta was developed. One and one-half miles southeast of the town of Keene, on the state road at Norton cemetery, there is an excellent display of a bisected delta. Around

Plate 24



H. L. Alling, photo. 1915

A portion of the terrace of Glacial Lake Wilmington, one-half of a mile west of Wilmington. Looking south.

the town of Wilmington the development of the terraces is exceptionally fine and thus the name is not inappropriate.[1]

As one investigates the terraces of the Wilmington lake from south to north in this area and in the Ausable quadrangle, the altitude rises at a rate of approximately 3 feet a mile and clearly illustrates postlacustrine deformation. The subject of uplift and tilting will be more fully treated beyond. A number of beaches of the lake are beautifully shown on a hill a mile directly north of

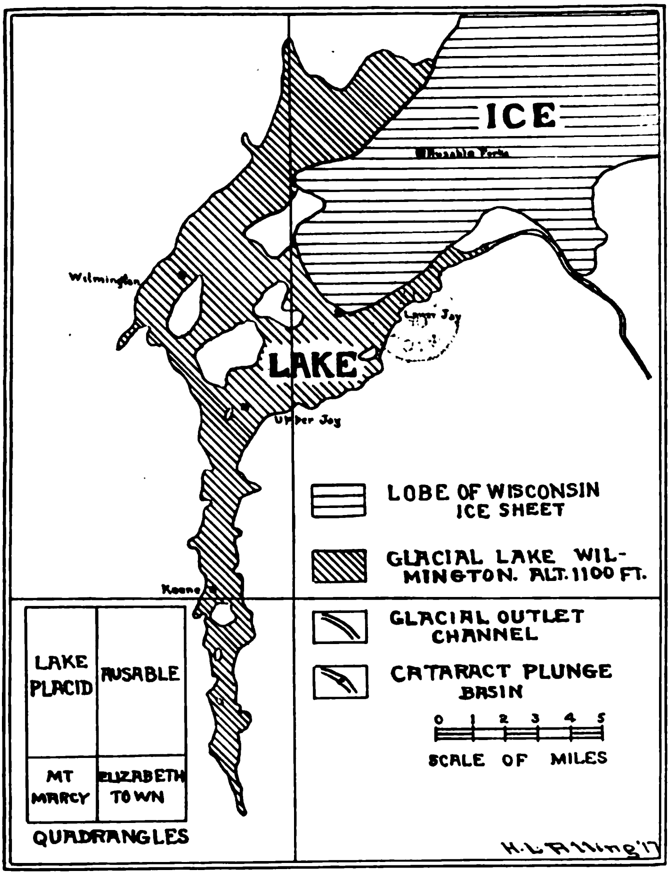


Fig. 6 The Glacial Lake succession in the Lake Placid quadrangle. Stage five.

St Huberts lake that succeeded the Saranac glacial waters is not shown in this series of maps. The lake that followed, the Wilmington lake, with an altitude of 1100 feet is given here. The outlet was to the east, through the gulf.

[1] Kemp, J. F., N. Y. State Mus. Bul. 21, p. 60.

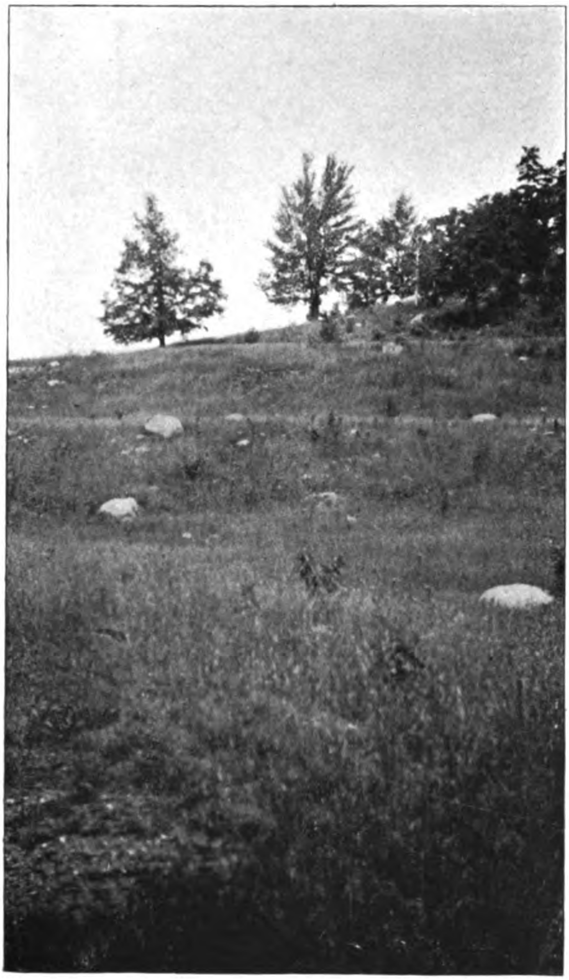
Keene, called by the writer "Keene hill." Here the altitude is 1113 feet. Farther north we find the outlet channel spillway at 1155 feet. This level, compared with the 1100-foot delta above mentioned, gives on calculation a deformation of 2.94 feet a mile.

Outlet. Once more we must depart from the Lake Placid quadrangle and consult the Ausable sheet to find the outlet. As can be inferred from figure 6 an ice lobe lay in the valley of the East branch of the Ausable river with its southern wall at Lower Jay. Another body of ice blocked the narrow valley now occupied by Trout pond. Thus northward escape was prevented. The waters of the lake found outlet to the east through the gulf, a narrow and deep faultline valley, south of Ellis and Black mountains. In this interesting channel there are a number of Pleistocene cataracts, but unfortunately the topography is incorrectly drawn and they fail to appear on the survey map. At the eastern end of the gulf, on the boundary between the townships of Jay and Chesterfield, the river turns to the southeast making a series of little ponds, which are really plunge basin lakes at the base of former cataracts. Of the group the remarkably beautiful Copperas pond is the most striking example.

Beaches versus stream terraces. Below the Wilmington lake level, on the mountain slopes, in the Ausable valley, a number either of benches or stream terraces have been found and their altitudes measured. The question of origin arises, naturally, in individual cases. Many of them are probably shore-line features formed by glacial lakes, while others are stream meander terraces formed by the postglacial Ausable in cutting its way through the glacial sands. A discrimination between the two is often impossible, thus leaving the identification of succeeding lake levels extremely unsatisfactory. Typical examples are the levels on the "Keene hill," a mile directly north of Keene (see plate 25). The following are the altitudes the writer has obtained by the use of two aneroid barometers checked against a barograph and spirit leveling: 1146, 1113 (Wilmington beach), 1037, 1017.7, 993.9, 985.7, 925.7 feet. The mean height of the river at this point is 816 feet. The origin of the lower ones is a disputed question. D. W. Johnson regards them as stream terraces, while Fairchild and Chadwick attribute them to glacial lakes.

Another series, in the Ausable sheet, 1½ miles northeast of Lower Jay on a similar hill (the "Lower Jay hill"), has been recorded as follows: 1046, 1043, 1024, 997, 917.5, 908 (wave-cut cliff), 880 and 857 feet. The river is a mile distant to the west,

Plate 25



H. L. Alling, photo, 1916

Probable glacial lake beaches 1 mile north of Keene, looking north. Altitudes: 925.7, 985.7, 993.9, and 1017.7 feet.

Plate 26

H. L. Alling, photo, 1916

Stream terraces or glacial lake breaches above Upper Jay, east side of the Ausable river. Looking east from the state highway Altitudes 738½ and 747½ feet.

Plate 27

H. L. Alling, photo, 1916

Stream terrace or glacial lake beach east of Upper Jay. Looking north. Altitude 747½ feet.

while the best development of the levels is on the east side of the hill. Here glacial lake origin seems certain. To the writer they have exactly the same appearance as those on the hill near Keene.[1] Other groups of benches in the Lake Placid quadrangle are important. On the hill north of the junction of Clifford brook (the "Clifford hill") and the Ausable, a series shows the following figures: 1074, 1070, 1020, 967 and 964. These are perhaps lacustrine in character, especially the 964-foot level which Johnson admits is a wave-cut cliff.

On the east bank of the river 3½ miles north of Keene ("Quarry point") a series of probable stream terraces ranges as follows: 1028, 970, 921, 912.5, 903, 879 and 859. Doctor Johnson examined them carefully with the writer and pronounced them the work of the river; he likewise so regarded the terraces east of Upper Jay (See plates 26 and 27).

Following the lead of Woodworth,[2] the writer has plotted upon a north and south plane the above data of beaches, terraces and sand plains to see how they correlate among themselves and with the proposed spillways (see figure 8), taking into account the post-lacustrine deformation and the 20° inclination of the isobases. This was done on the basis of Fairchild's recent studies which furnish the approximate total uplift and amount of differential tilting for the area by means of isobases. It is interesting to note that a large number of these disputed levels fit into the general scheme and thus strongly suggest glacial lake origin. The writer is not, however, unmindful that pure coincidence may bring into line a group of stream terraces that really have no relation to one another. After lining up all available data there remained isolated figures that are impossible to pigeon hole. It is quite possible that with more careful examination in the field corresponding levels will be found, but as the matter now stands there is some doubt as to the character of some of the levels. With this uncertainty in mind we shall, however, now discuss the next level, which probably represents a glacial lake.

Upper phase of the Upper Jay lake. The Upper Jay lake, like its predecessor, the Wilmington lake, has left terraces and beaches that are very definite in character. One of the beaches on the "Keene hill" is 1017.7 feet in altitude, while a similar one on the

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[1] Compare pl. 22, fig. 2, facing p. 658 in Bul. Geol. Soc. Amer., v. 27.

[2] Woodworth, J. B., Ancient Water Levels of the Champlain and Hudson Valleys, N. Y. State Mus. Bul. 84, pl. 28.

"Lower Jay hill" presents a beach at 1046 feet. This gives upon calculation an uptilt to the shore line of 2.80 feet a mile. The outlet of the lake is not definitely known, but a pass one-half of a mile directly south of Haystack mountain in the Ausable quadrangle (not the mountain of the same name in the Marcy range) has an altitude (1153 feet) that gives the proper figure when the tilting is calculated. When visited, however, this pass did not show evidences of stream action. The area is entirely fine sand, but farther north a possible channel, 1½ miles north of Bald mountain, is suggested as a more probable control.

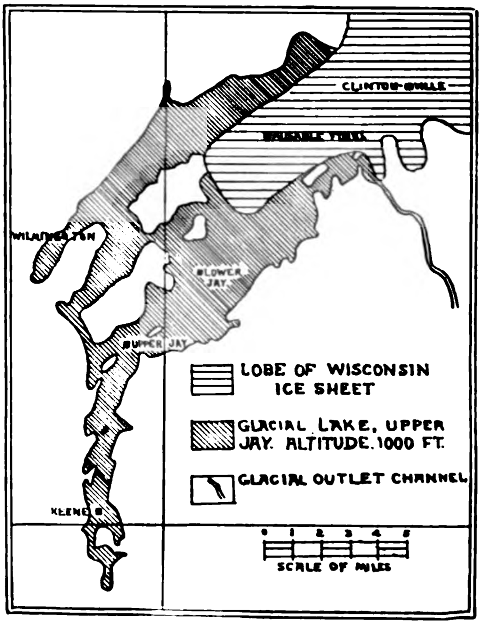


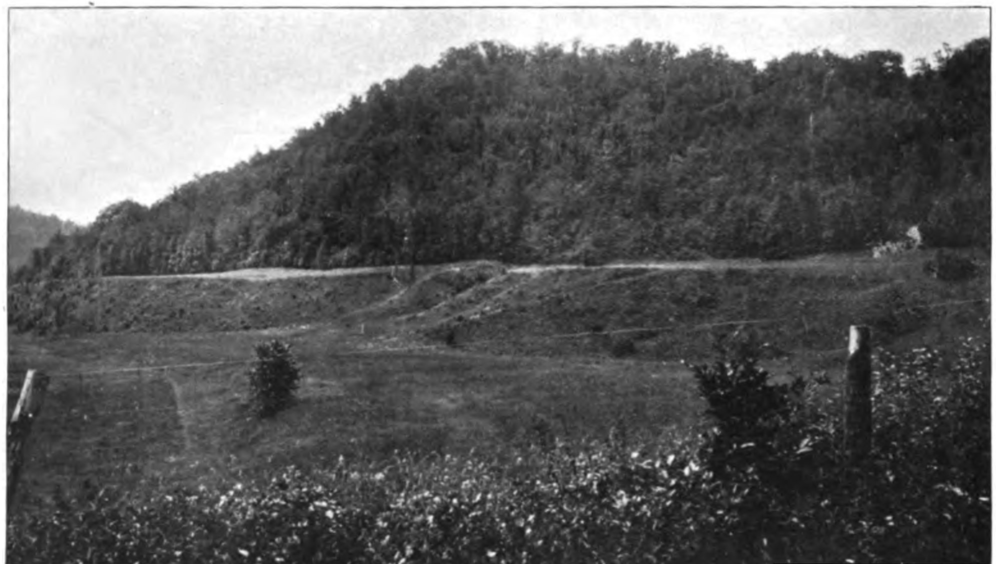
Fig. 7 **The Glacial Lake succession in the Lake Placid quadrangle. Stage six.**

Following the Wilmington lake, the Upper Jay lake formed in the valley of the East Branch of the Ausable river. The lower levels are not shown in this series.

Lower phase of the Upper Jay lake. A lower phase of the Upper Jay lake is indicated by beaches on the "Keene hill" at 993.9 feet and a beach at 999.5 feet on the slopes of Oak ridge and a level at 1024 feet on the "Lower Jay hill." These figures give the value, 2.75 feet a mile for the tilt.

Haselton lake. A possible lake with an altitude of 967 feet around the town of Keene has left terraces, wave-cut cliffs and

Plate 28



H. L. Alling, photo, 1916

Stream meander scarp terraces near the junction of Clifford brook and the East branch of the Ausable river. Altitudes: 904, 973, and 1026 feet.

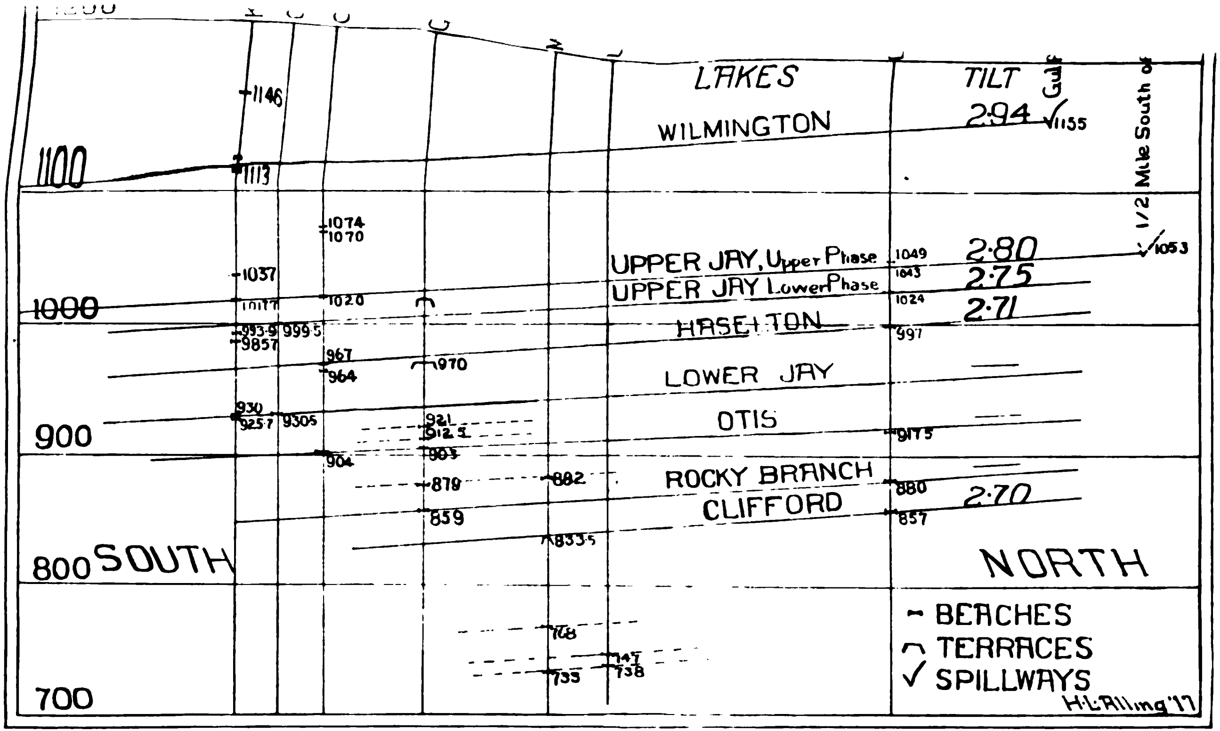
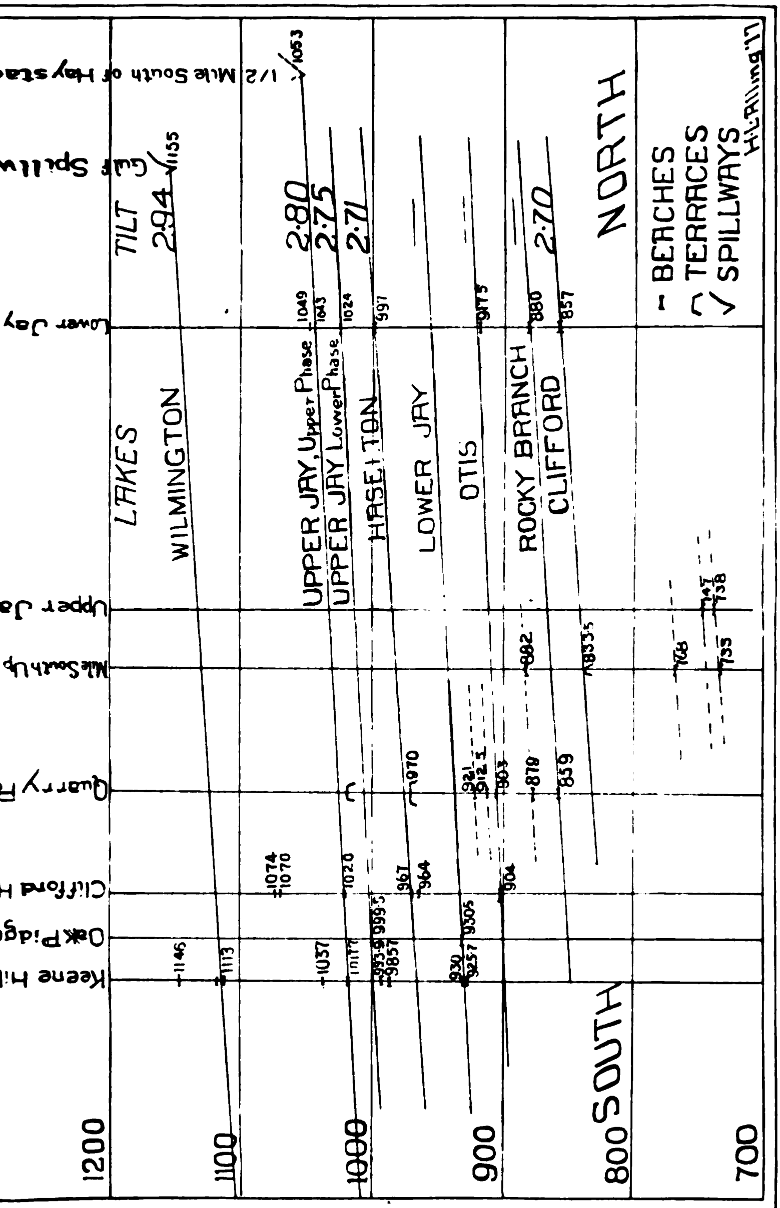


Fig. 8 Profile of the Glacial Lake Levels in the Lake Placid quadrangle.
The small numbers refer to altitudes.
"Keene Hill"—a mile north of Keene.
"Oak Ridge"—a mile and a half north of Keene.
"Clifford Hill"—just north of the junction of Clifford Brook with the Ausable river.
"Quarry Point"—three and a half miles north of Keene.
"Lower Jay Hill"—a mile and a half northeast of Lower Jay, Ausable quadrangle.

Plate 29

H. L. Alling, photo, 1916

Wave-cut moraine, one-fourth of a mile north of Clifford brook, west side of Ausable river. Altitude 976 feet.



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"Quarry Point"—three and a half miles north of Keene.
"Lower Jay Hill"—a mile and a half northeast of Lower Jay, Ausable quadrangle.

beaches. The amount of tilt based upon the wave-cut cliff on the "Clifford hill" at 964 and a level on the "Lower Jay hill" with a figure of 997 is 2.71 feet a mile. Relatively small sand plains of this lake are well shown about the town of Haselton village in the Lake Placid sheet.

The controlling outlet is unknown, but the writer offers the suggestion that it may have been a one-bank channel on the north side of Haystack mountain (Ausable sheet) carrying the waters east, for there is some evidence of water action in that region.

Lower Jay lake. This lake level is very definite and no question seems to exist as to its nature, although the "Lower Jay hill" does not show a corresponding level. About Keene there are wave-cut terraces at 930 and 930.5 feet. A well-preserved terrace bottom is located 1½ miles south of Upper Jay with an average height of 930 feet (see plate 30), and likewise a fine sandy plain on the western edge of the Lake Placid quadrangle which continues on to the Ausable sheet where we find Otis brook flowing on the eastern edge. Here the altitude is about 940 feet. We have not sufficient data to calculate the amount of tilt.

Otis lake. The level called the Otis lake is one of the more doubtful levels, as sufficient data are not at hand to determine whether it is a lake feature or a system of stream terraces. If we take a level that Johnson regards as a stream terrace 1¼ miles north of Keene at 903 feet and a beach on the "Lower Jay hill" at 917.5 feet, we obtain an unsatisfactory value of 2 feet a mile for the tilt, which of itself seems to cast some doubt upon the glacial lake origin of the level. Errors in the measurements may, however, be a contributing cause for the discrepancy.

Rocky Branch lake. Rocky Branch lake is recognized on the basis of three terraces around the villages of Upper and Lower Jay, and upon some of the disputed levels. The latter are 1¼ miles north of Keene, 858 feet, and on the "Lower Jay hill" at 880 feet, giving a tilt of about 3 feet a mile, which is approximately the expected value. Although the outlet is unknown, the terraces are definite in character and thus this level should rank as definitely settled.

Clifford lake. This is the last and lowest of the levels definitely recognized within the confines of the Lake Placid quadrangle. Its origin is still in doubt, although a warp of 2.70 feet to the mile is indicated by a beach or stream-terrace a mile south of Upper Jay

Plate 30

H. L. Alling, photo, 1916

Lake bottom of Glacial Lake Lower Jay. One and one-half miles south of Upper Jay. Looking north. Altitude 930 feet.

at an altitude of 833.5, and another one on "Lower Jay hill" at 857 feet.

Lower lake levels. At still lower altitudes several more of these perplexing levels were found, but as they are largely outside the Lake Placid quadrangle they will not be discussed. Suffice to say, the most prominent level in the lower Ausable valley is the ***marine plain*** in the vicinity of Ausable Forks. Here the measured altitudes agreed within a foot of the value called for by Fairchild's figures.

Cause of the large amount of material available for the formation of terraces. One of the striking features of the glacial geology of the Adirondacks is the small amount of true morainal material[1] unmodified by water[2] as contrasted with the vast quantities of sand and gravel in deltas, terraces etc., when compared with other districts, such as the Catskill mountains. The following hypothesis is offered to account for this. It is generally conceded that with the return of warmer climate the Adirondacks were completely surrounded by a vast ring of ice that isolated the Adirondack highland from the rest of the state.[3] It was during this stage that the glacial lakes here described existed. The great ice sheet undoubtedly destroyed all vegetable life in both the Adirondacks and the Catskills, but in the latter case the ice retreated northward as an irregular edge which allowed vegetable life to follow the ice in its withdrawal. This condition was not possible in the Adirondacks where the ice ring prevented much if any encroachment on the part of plants into the ice-deforested area. In the Catskill region the glacial drift was anchored by the roots of newly growing shrubs etc. and thus it was not easily washed by the streams into the standing waters in the valleys below, so a large amount of the drift still remains on the slopes. On the contrary, the glacial debris in the Adirondacks was not anchored and most of it has been carried down into the valley bottoms and there worked over into lake deposits.

Postlacustrine deformation and tilting. It has been pointed out that at the maximum extent of the Wisconsin ice-body, the load upon the land surface must have been tremendous and must have compressed the land below its former level.[4] Since the ice was

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[1] Cushing, H. P., N. Y. State Mus. Bul. 115, p. 495.

[2] Ogilvie, I. H., Jour. Geol., 10:397-412. 1902.

[3] Fairchild, H. L., N. Y. State Mus. Bul. 160, pl. 11.

[4] This subject of deformation has not received the attention of structural geologists in the light of isostasy.

thicker in the north than in the south, the amount of deformation was greater in the northern part of the State. With the removal of the load by the melting of the ice the land has " sprung " back, thus elevating the surface, tilting the shore-line features of the glacial lakes. It has been shown by Fairchild[1] that the character of the postlacustrine uplift was a lifting in the form of a warped plane with the amount of warping greater to the north. The lines of equal uplift since the marine level are inclined west-northwest to the east south-east (20° from the latitude parallels). The zero isobase passes far south of New York City. The 600-foot isobase enters the Lake Placid quadrangle at the very southeast corner of the map. The northeast corner is cut by the 648-foot isobase. These figures give the total uplift for the region since the marine waters occupied the Hudson-Champlain strait. The figure for the amount of tilting for this datum plane in this region, is 2.71 feet a mile taken along a north and south line, or 2.83 feet perpendicular to the isobases.

Although Fairchild's papers form a very valuable contribution to this subject, there exists some uncertainty as to the character of the uplift. (1) Was the upward movement gradual and uniform or (2) was it in the nature of a wave or a series of sudden uplifts? The writer believes that the problem will be clarified by the measurement of beaches, deltas etc. situated at higher levels than the marine plain to supplement those mapped at the lower altitudes. The shore phenomena of the lakes above described afford an opportunity to determine the amount of tilt of the land surface, for they furnish a series of datum planes higher than those in the Champlain valley, which was occupied by ice during the entire period that the lakes existed. Fairchild believes that his figures give the *total* uplift since glacial time. The writer feels, however, that this conclusion is based upon the state of affairs that prevailed during and after the marine stage and overlooks the shore phenomena of higher lake levels. Although accurate measurement of the amount of tilt of the lake levels of the Lake Placid quadrangle is an extremely difficult matter (for the chance of error is great), the table given below would indicate that the uplift was taking place while the ice was melting from the area.

[1] Fairchild, H. L., Pleistocene Uplift of New York and Adjacent Territory, Bul. Geol. Soc. Amer., 27:235-62. Post-glacial Marine Waters in Vermont, Rep't of Vt. State Geol. for 1915-1916, p. 1-41. 1917.

Deformation table for the lower series of lakes in the quadrangle

Lake	Altitude in feet	Calculated tilt, feet a mile
Wilmington	1100	2.94
Upper phase of Upper Jay	1016	2.80
Lower phase of Lower Jay	994	2.75
Haselton	967	2.71
Lower Jay	930	....
Otis	903	....
Rocky branch	860	....
Clifford	835	2.70
Marine level	648	2.71

The writer came to the same conclusion in 1916 although at that time his data were not so accurate as those now available, and hence the figures are slightly different.

It will be noticed that the rate of tilt decreases as one passes from Lake Wilmington to Lake Haselton; the tilt of the latter appears to be the same as that of the marine plain. If any confidence can be placed in the figures, it would seem that the lakes below and including Haselton drained directly into the marine waters. Since warping is a function of uplift, it would appear that the total amount of uplift for the quadrangle since glacial times is greater than the amount, 600 feet (for the southeast corner), proposed by Fairchild.

ACKNOWLEDGMENT

The writer is indebted to Professors James F. Kemp, Herman L. Fairchild, George H. Chadwick and D. W. Johnson for advice and counsel in the field and in the laboratory.

HISTORICAL GEOLOGY[1]

Precambrian History

The oldest records of the Lake Placid quadrangle are written in the rocks of the Grenville series. A most conservative estimate by geologists gives the age of the Grenville strata as no less than 25 or 30 million years, but it must be admitted that we have no means of accurately measuring geologic time in years. Since the Grenville rocks are distinctly stratified, very thick (many thousands of feet), and of wide areal extent not only throughout the Adirondacks, but also in eastern Canada, we may be sure that the earliest known condition of the area of the quadrangle was a sea in which the Grenville sediments were accumulated layer upon layer on the bottom.

After the deposition of the Grenville strata came vast intrusions of molten masses, including first the upwelling of the great body of anorthosite in Essex and Franklin counties, and second the still greater syenite-granite body, these two igneous series being by far more extensively developed than any other rocks of the quadrangle.[2] During the processes of intrusion and cooling of the magmas, the anorthosite differentiated into the Marcy and Whiteface types, and the syenite-granite split up into various types ranging from rather basic (dioritic) phases, through quartz syenite, granitic syenite, and granite to even granite porphyry. The syenite-granite intrusion appears to have taken place not long (geologically) after the anorthosite intrusion so that the latter was still hot, though probably not molten, and it was locally assimilated along the borders of the invading syenite-granite magma, thus giving rise to the rock called the Keene gneiss.

The whole Adirondack region was raised well above sea level most likely at or near the time of the great intrusions. There are strong reasons for believing that none of the rocks were ever highly folded by orogenic movements, but that the breaking up and tilting of the Grenville strata resulted from the upwelling of the great bodies of magma; that the metamorphism of the Grenville

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[1] A treatise dealing with the geography and geological history of the Adirondack region in somewhat untechnical language was prepared by the writer and was published as Bulletin 193 of the State Museum under the title "The Adirondack Mountains."

[2] As already suggested, possibly some gabbro now represented by amphibolite, was intruded before the anorthosite.

strata preceded, or possibly was in part at least concomitant with, the great intrusions; and that the foliated character of the intrusive rocks is essentially a flow-structure developed under moderate pressure during late stages in the consolidation of the magmas.

The great Precambrian land mass just referred to was above sea level, and underwent weathering and erosion for some millions of years at least, extending through later Precambrian time and into the early Paleozoic era, as proved by the facts that the oldest rocks deposited upon the Precambrian floor are of late Cambrian age, and that the rocks of this Precambrian floor immediately below the Cambrian strata exhibit textures and structures which could not possibly have been produced except at very considerable depths below the earth's surface.

Following the anorthosite and syenite-granite intrusions and, for most part at least, during the long time of erosion above mentioned, came the minor intrusions of gabbro-diorite, gabbro, pegmatite and diabase. Of these, the diabase is the youngest with the finest grained texture showing a cooling of the rock comparatively near the surface of the earth. In the Adirondack region, pegmatite dikes commonly cut the gabbro and hence are younger. Whether the gabbro bodies are younger or older than the gabbro-diorite dikes of the Lake Placid quadrangle could not be positively determined but they are probably younger.

Paleozoic History

By late Cambrian time the profound erosion above referred to had worn down the whole Adirondack region to a comparatively smooth, low-lying (peneplain) surface. This is proved by the fact that the late Cambrian strata (particularly the Potsdam sandstone), which are the oldest to have been deposited upon the Precambrian rocks, everywhere rest upon a peneplain surface of the latter. In the northeastern Adirondacks, including the Lake Placid quadrangle, this peneplain was moderately rough with some hills rising probably several hundred feet above the general level, but of course this was not at all comparable to the high, rugged relief of the present day.

The best available evidence indicates that the ancient peneplain became sufficiently submerged during late Cambrian time to allow the sea to cover all but a considerable part of the central Adirondack area, and that the maximum submergence occurred during mid-Ordovician time when a still smaller part of the central Adirondack region remained as a low island. Judging by the marine

character, thickness and present-day distribution of the Cambrian and Ordovician strata, the late Cambrian sea probably covered some of the area of the Lake Placid quadrangle, and the mid-Ordovician sea quite certainly covered some, or possibly most, or all, of the area of the quadrangle. However extensive the Cambrian and Ordovician rocks may once have been, they have since been completely removed by erosion from the area of the quadrangle.

At some time or times during the middle or late Paleozoic era the whole Adirondack region, then largely mantled with Paleozoic sediments, was raised well above sea level. Some of this upward movement may have taken place at the time of the Taconic revolution (at the close of the Ordovician), though it is generally considered that the major uplift occurred at the time of the Appalachian revolution (toward the close of the Paleozoic). In northern New York this upward movement was not accompanied by folding of the rocks, but there was a general tilting of the strata downward toward the south or southwest.

Mesozoic History

The erosion cycle inaugurated by the Paleozoic elevation of northern New York continued for a vast length of time, or till late in the Mesozoic era or early in the Cenozoic era, when the Paleozoic strata were largely removed from the Adirondack area and another eroded surface approaching the condition of a peneplain was produced. This is commonly referred to as the Cretaceous peneplain. Apparently this peneplain was least perfectly developed in the central and east-central Adirondack area, including the area of the Lake Placid quadrangle, where various hard rock masses (monadnocks) stood out more or less prominently above the general level. This peneplain was upraised late in the Mesozoic era or early in the Cenozoic era, and distinct remnants of it in northern and central New York now lie at altitudes of from 2000 to 3000 feet or possibly more in some places. Within the quadrangle, however, no very accurate idea of this peneplain or its remnants can be gained because it was only imperfectly developed there.

It is quite certain that much of the faulting which has so largely influenced the major topographic features of the eastern and southern Adirondacks took place after the production of the so-called Cretaceous peneplain, and probably at the time of its uplift. Some zones of fracture, however, like the Wilmington

notch fault, whose displacements show little, if any, in the existing topography, are probably much older, and they may in part at least be of Precambrian age. Some of the fracturing is certainly of later age than the diabase dikes because several of these in the Lake Placid quadrangle have been crushed by the faulting.

Cenozoic History

The major existing relief features of the Lake Placid quadrangle have been produced chiefly by the dissection of the upraised late Mesozoic or early Cenozoic peneplain. As a result of the uplift the streams were greatly revived as erosive agents, and they proceeded to carve out channels and valleys principally along the comparatively weak belts of Grenville rocks and the fault zones of weakness.

Late in the Cenozoic era the area of the quadrangle, in common with most of the State, was deeply buried under the great ice sheet of the Glacial epoch.[1] The continental ice body in passing across the quadrangle, in a south-southwesterly direction, removed the residual soil of interglacial periods and subdued the contours of the mountains. The tongues of the waning ice were influenced by the topography, as is shown by the striae and the ice action in the narrow valleys. In retreating from such valleys both ends were blocked by moraines, usually forming basins between for the accumulation of lakes. Many other, but more open, valleys were dammed, producing lakes such as Lake Placid. The preglacial stream valleys were likewise blocked and in some localities, as in the case of the Ausable river near Keene, were forced to seek new channels.

The ice sheet left a mantle of till all over the area but much of it has been washed into the valley bottoms where it was worked over by the glacial lakes that were brought about by the ice damming the normal drainage lines. Continuing after the withdrawal of the ice body local glaciers persisted for a time on the slopes of the higher mountains, as is indicated by the moraine in the cirque on Esther mountain.

It is the belief of the writer that the Lake Placid quadrangle was situated near the northeast rim of the ring of ice that surrounded and isolated the Adirondack highland from the rest of the State during the retreat of the great ice sheet, and thus the northward-draining valleys were blocked, preventing the escape of the

[1] The summary of the Glacial and Postglacial history was written by Mr H. L. Alling.

vast quantities of waters which flooded the district with lakes. These bodies of water, especially at the higher levels, did not leave distinct shore-line features, for their outlets were controlled by ice lobes which caused constant or periodic lowering of their surfaces.

The district covered by the glacial lakes here described can be divided into two sections, the western and the eastern. It is contended that the western section was the first to be relieved of ice, thus giving birth to the South Meadows lake. The uncovering of lower outlets to the west extinguished this lake which was succeeded by Upper Lake Newman. During this stage the ice lobe that lay in the East branch of the Ausable river, eastern section, retreated to allow the Keene lake to form, with its drainage to the south. Further withdrawal of the lobe uncovered the Wilmington notch and thus the waters of the Keene lake fell to the level of Upper Newman, bringing about a union of the two sections. Succeeding Upper Newman, Lower Newman held the stage until the lobe in the Elizabethtown valley opened the side-outlet channels in the center of the Ausable sheet, then the Saranac glacial waters held dominion, draining east. During the lower stages the western section was drained and only the eastern section was flooded.

On leaving the higher levels we descend to the better defined shore lines and levels left by lakes whose outlets were over rock. The Wilmington lake, drained through the gulf, and the Upper Jay lake, both upper and lower phases, likewise drained to the east. The impossibility of distinguishing beaches and stream terraces in certain cases leaves in doubt the exact nature of some of the lower levels; the marine plain around Ausable Forks being the most important of the lower series.

The nature of the postlacustrine uptilting, which inclined the shore lines of the lakes northward, points to the conclusion that the land was experiencing uplift and warping while the ice was retreating from the region. The total amount of uplift since glacial times for the quadrangle was greater than 600 feet.

STONE QUARRIES AND MINES

The accompanying geologic map shows the locations of nineteen stone quarries and mines or prospect holes.

Road Metal

Excellent rocks for use in the construction of macadamized roads occur in inexhaustible quantities within the quadrangle.

Most of the rocks actually used for such purposes are from the anorthosite and the syenite-granite series. These make a good grade of road metal. Quarries have been opened in Marcy anorthosite 1½ miles northeast of Upper Jay, and at the southern base of Hamlin mountain; in Whiteface anorthosite just south of The Flume; in normal syenite at the eastern base of Cobble hill, and near High fall; in a basic phase of syenite by the road 1 mile north of Malcom pond; in Grenville and Whiteface anorthosite mixed rocks by the road 3¼ miles north of Keene; and in weathered Grenville limestone by the road one-half of a mile north of Franklin Falls.

Building Stone

Fresh rock from most any portion of the great intrusive masses of anorthosite or syenite-granite would yield excellent building stone of great strength and durability, and often of unusual beauty. Two small quarries have been opened at the southern margin of the Pulpit mountain gabbro stock to furnish stone for the construction of a nearby reservoir. No other building stone quarries worthy of special representation on the map were found within the quadrangle.

Limestone for Lime

There are several quarries from which Grenville limestone was obtained many years ago and burned to lime in nearby kilns. These are indicated on the map 1½ miles north-northwest of Keene; on the hillside 3¼ miles north of Keene; near Woodruff fall; and just west of Middle Kilns.

Iron Ore

There are two localities from which a little magnetic iron ore was obtained many years ago. One of these is a small opening on the hillside 1 mile west-southwest of Keene. The ore occurs in small, irregular masses in the syenite and Grenville mixed gneiss area apparently as segregation masses in the syenite.

The other locality is near the eastern base of Marble mountain about 1½ miles southwest of Wilmington. There are two small openings in a rather coarse phase of Whiteface anorthosite, the magnetite occurring as irregular masses up to an inch across in a pegmatite dike.

Graphite

As above stated, graphite (so-called "black lead") often occurs in small flakes in the Grenville limestone and certain of the schists and gneisses. So far as the writer could learn, there have been only

two attempts to mine this mineral within the quadrangle, this having been in a small opening in the little area of Grenville limestone one-half of a mile south-southeast of Franklin Falls. The limestone contains numerous flakes of graphite, but apparently a vein of fibrous graphite less than an inch wide in the limestone was the center of interest.

Mr Alling has described a recent attempt to develop a graphite mine 2½ miles west-northwest of Wilmington on the side of Wilmington mountain.[1] This work has been done since the writer's survey of the region. According to Alling the last operations were in the spring of 1917. Several prospect pits or small shafts were sunk. The main rock is a coarsely crystalline Grenville limestone with large flakes of graphite. Associated with this limestone are some green pyroxene and red garnet rocks, and some basic pegmatite.

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[1] N. Y. State Mus. Bul. 199. 1918, p. 36–37.

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New York State Museum

JOHN M. CLARKE, DIRECTOR

GEOLOGY OF THE SCHROON LAKE QUADRANGLE

By

WILLIAM J. MILLER

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1919

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Science Department, November 12, 1918

Dr John H. Finley
President of the University

Sir:

I transmit to you herewith and recommend for publication as a Bulletin of the State Museum, a manuscript entitled *Geology of the Schroon Lake Quadrangle* which has been prepared, at my request, by Prof. William J. Miller.

This report is accompanied by necessary maps.

Very respectfully yours

John M. Clarke
Director

Approved for publication this 13th day of November, 1918

John H. Finley

President of the University

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John M. Clarke, Director

GEOLOGY OF THE SCHROON LAKE QUADRANGLE

By WILLIAM J. MILLER

GENERAL GEOGRAPHIC FEATURES

The Schroon Lake quadrangle[1] represents an area of approximately 215 square miles in the central-eastern portion of the Adirondack mountain region. The territory is all in Essex county except the southern margin, which lies in Warren county. All the quadrangle is rugged, moderately mountainous, and mostly a wilderness, in these respects being quite typical of the 10,000 square miles of the Adirondack region.

The southern half of the quadrangle is less rugged than the northern and contains several farms, roads and villages. Schroon Lake, the largest village, is a well-known summer resort situated near the northern end of the lake of the same name. The other principal villages are Minerva, Olmstedville, South Schroon and Adirondack.

No railroad enters the quadrangle, the nearest being the Adirondack branch of the Delaware and Hudson with stations at Riverside and North Creek in the northern portion of the quadrangle next to the south.

The northern half of the quadrangle is notably more mountainous and less settled, there being but one traveled highway (the Newcomb and Port Henry road) across it. All the permanent settlements of the northern portion of the quadrangle, including the little village of Blue Ridge, are located on this road.

[1] See map in pocket of back cover of this bulletin.

Both the highest and most rugged mountains are in the northeastern one-fourth of the quadrangle. Hoffman mountain is the highest with an altitude of 3715 feet, but it does not stand out as a conspicuous peak because it is simply the loftiest of a considerable group of mountain summits in this vicinity. In this northeastern quarter, no other mountain rises to 3500 feet, but several lie between 3000 and 3500 feet, like Wolf Pond mountain (3473), Ragged mountain (3290), Sand Pond mountain (3040), Texas ridge (3212), and several unnamed points on Blue ridge.

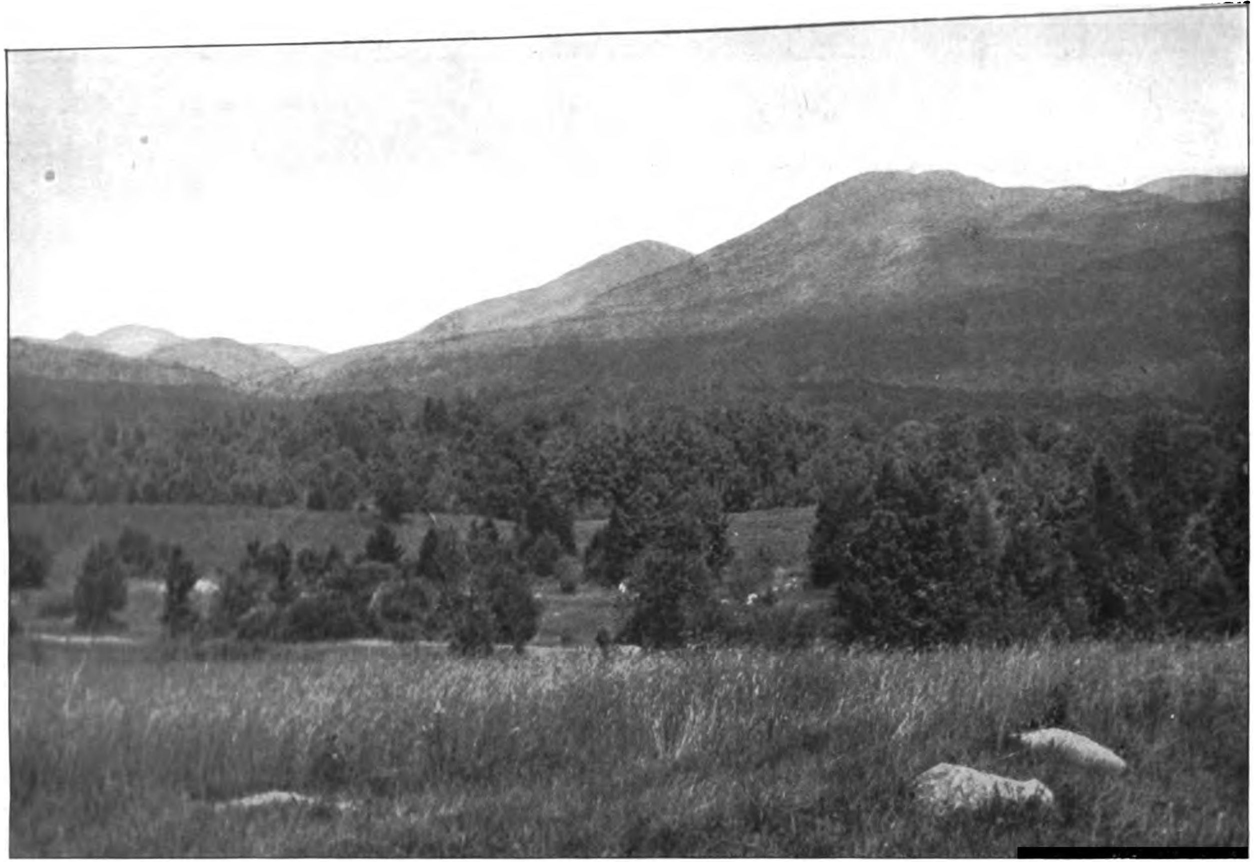
In the northwestern quarter of the quadrangle the country is notably less mountainous, the highest summits being Bailey hill (3115), the western peak of Sand Pond mountain (2970), and Hewitt Pond hill (2480+).

In the southern half of the quadrangle no peak rises to 3000 feet, and only three rise to 2500 feet or more, these being Ore Bed mountain (2856), a peak 1 mile northeast of Ore Bed mountain (2584), and Hayes mountain (2822). A number of others have altitudes between 2200 and 2500 feet, among them being Cobble hill, Oliver hill, Beech hill, Pine hill, Green hill, Moxham mountain, and a group of points around Barnes pond.

There is a marked tendency for the mountains and valleys to show a north-northeast by south-southwest trend. Among the more or less well-defined ridges are the following: from Bailey hill, through Hayes and Ore Bed mountains, to Moxham mountain (12 miles); from north of Ragged mountain, through Sand Pond mountain, Washburn ridge, and Bigsby hill, to south of Oliver hill (14 miles); Texas ridge (3 miles); Blue ridge (7 miles); Beech hill to south of Pat pond (6 miles); and from Dirgylot hill, through Severance hill, Hedgehog hill, and Merrills hill, to Ledge hill (10 miles). For the most part these ridges are separated by narrow, nearly straight valleys. The most notable exception is the fairly well-defined east-west valley which the road follows across the northern part of the quadrangle.

Schroon river, by means of a network of tributaries, drains all the area of the quadrangle except most of the northeastern portion, which is drained by Boreas river. Both the Schroon and the Boreas pass into the Hudson river.

Altogether, there are about 30 lakes and ponds, the largest being Schroon lake with 7 miles of its length within the quadrangle. Next largest are Cheney pond nearly 2 miles long, and Hewitt pond about 1 mile long.



W. J. Miller, photo, 1916

General view of the mountains looking north and northeast from Warren's hotel, 1 mile southeast of Bailey pond. Texas ridge on the right and Hoffman notch on the left

GENERAL GEOLOGIC FEATURES AND PUBLICATIONS

Most of the more common and well-known rock formations of the Adirondack region, as well as certain unusual ones, are abundantly represented in the Schroon Lake quadrangle. In the regular order of their geologic ages the principal rocks are as follows:

- Pleistocene
  - Glacial and Postglacial deposits
- Paleozoic (Cambrian)
  - Little Falls (?) dolomite
  - Potsdam sandstone
- Precambrian
  - Diabase dikes
  - Aplite and pegmatite dikes
  - Gabbro stocks and dikes
  - Keene gneiss, and assimilation product of the anorthosite and syenite-granite series
  - Syenite-granite series
  - Anorthosite series
  - Grenville series of metamorphosed strata

The Precambrian formations constitute the foundation rocks of the entire quadrangle. Oldest of all are the Grenville strata, probably of Archeozoic age, which are thoroughly crystalline. Grenville strata are well developed in the southern half of the quadrangle, but their distribution is very "patchy" because they were invaded and cut to pieces by great masses of intrusive rocks.

Next to the oldest known is the anorthosite series which occupies most of the northeastern half of the area. The great bulk of this rock is very coarse grained and highly feldspathic (Marcy anorthosite), but it has a more or less well-defined border development (Whiteface anorthosite).

The syenite-granite series, so common throughout the Adirondack region, is next in order of age, being clearly intrusive into both the Grenville and the anorthosite. This series, more particularly its granite facies, is wholly confined to the southwestern half of the quadrangle where it is the most prominent rock formation.

Several considerable areas of Keene gneiss lie in general between the anorthosite and syenite or granite areas. This rock is regarded by the writer as an assimilation product which resulted from the incorporation and digestion of anorthosite by the molten syenite-granite.

Gabbro stocks and dikes of the usual Adirondack sort are prominently developed in the southwestern half of the quadrangle, each of two of the stocks occupying several square miles.

Pegmatite and diabase dikes of the usual kinds, both later than the gabbro, are well represented. A few small dikes of aplite were also observed cutting the gabbro.

Two small areas of Paleozoic strata are known in and near Schroon Lake village. One of these is Potsdam sandstone and the other is Little Falls (?) dolomite.

Fifteen faults and zones of excessive jointing have been located and these have notably influenced the topographic development.

Pleistocene deposits are very widespread, being especially thick in the more prominent valleys where the underlying rocks are in many places effectually concealed by them.

The following list includes the principal publications which contain statements regarding the Schroon Lake quadrangle itself and the adjoining districts, as well as certain other papers which aid in understanding the geologic features of the quadrangle:

1842 **Emmons, E.** Geology of the Second District. Pt 2 of The Geology of New York

1879 **Hall, C. E.** Laurentian Magnetic Iron Ore Deposits of Northern New York. N. Y. State Mus. Rep't 32, 1879. p. 133-40

1895 **Kemp, J. F.** Preliminary Report on the Geology of Essex County. 15th Annual Rep't N. Y. State Geol., p. 590-604

1897 **Kemp, J. F. & Newland, D. H.** Preliminary Report on the Geology of Washington, Warren, and Parts of Essex and Hamilton Counties. 17th Annual Rep't N. Y. State Geol., p. 547-48

1897 **Kemp, J. F.** Physiography of the Eastern Adirondack Region in the Cambrian and Ordovician Periods. Geol. Soc. Amer. Bul. 8, p. 408-12

1902 **Finlay, G. I.** Preliminary Report of Field Work in the Town of Minerva, Essex County. 20th Annual Rep't N. Y. State Geol., p. 196-102.

1905 **Cushing, H. P.** Geology of the Northern Adirondack Region. N. Y. State Mus. Bul. 95

1905 **Ogilvie, I. H.** Geology of the Paradox Lake Quadrangle. N. Y. State Mus. Bul. 96

1906 **Kemp, J. F.** The Physiography of the Adirondacks. The Popular Science Monthly, March 1906

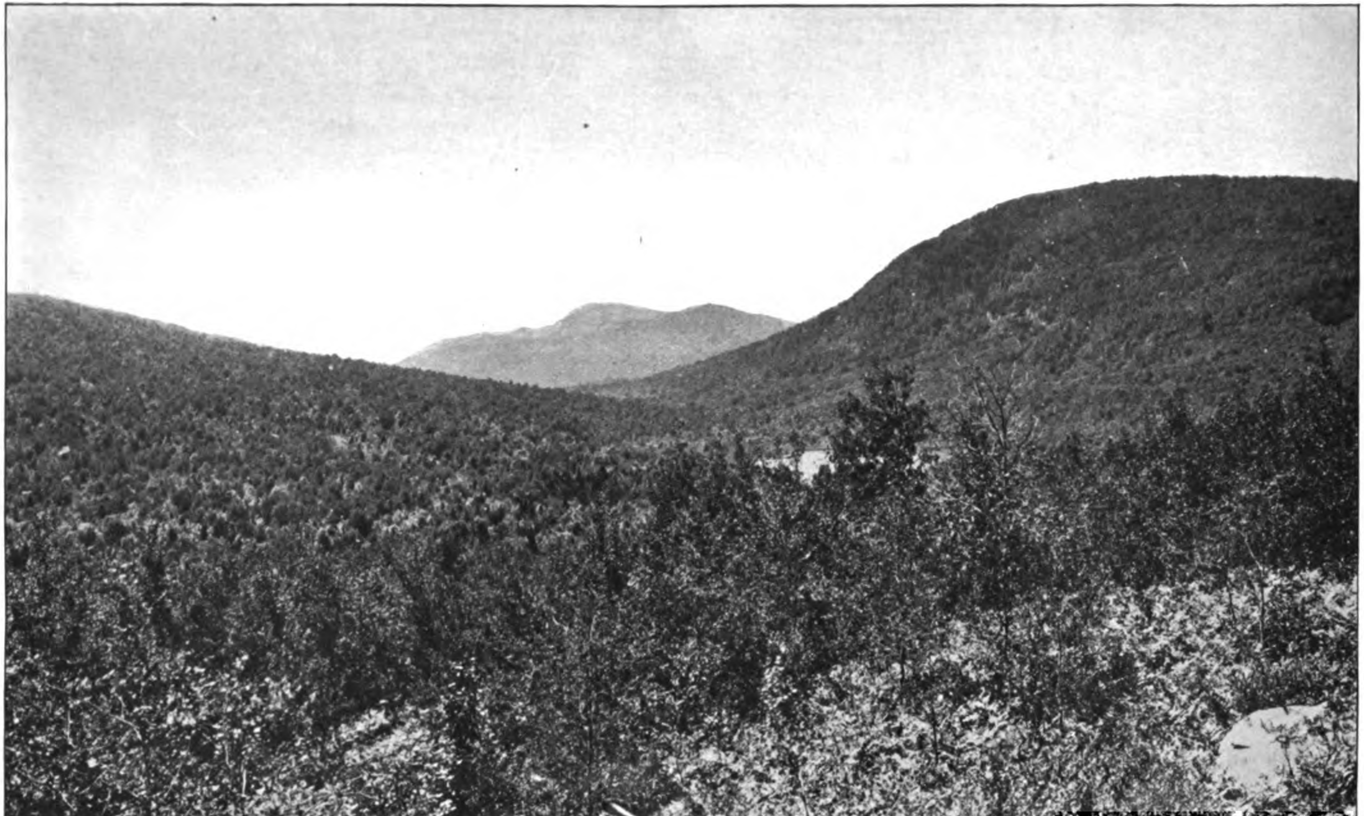
1910 **Kemp, J. F. & Ruedemann, R.** Geology of the Elizabethtown and Port Henry Quadrangles. N. Y. State Mus. Bul. 138

1912 **Miller, W. J.** Early Paleozoic Physiography of the Southern Adirondacks. N. Y. State Mus. Bul. 164, p. 80-94

1913 **Miller, W. J.** The Geological History of New York State. N. Y. State Mus. Bul. 168

1914 **Miller, W. J.** Magmatic Differentiation and Assimilation in the Adirondack Region. Geol. Soc. Amer. Bul. 25, p. 243-61

Plate 2



J. W. Forrest, photo, Troy, N. Y.

A view southeast from a point one-half mile northeast of Bailey pond. Bailey pond near the middle, Hayes mountain on the right, and Ore Bed mountain in the distance.

1914 **Miller, W J.** Geology of the North Creek Quadrangle. N. Y. State Mus. Bul. 170

1916 **Miller, W. J.** Origin of Foliation in the Precambrian Rocks of Northern New York. Jour. Geol., 24:578-619

1917 **Miller, W. J.** The Adirondack Mountains. N. Y. State Mus. Bul. 193

1918 **Miller, W. J.** Adirondack Anorthosite. Geol. Soc. Amer. Bul. vol. 29, no. 4

PRECAMBRIAN ROCKS

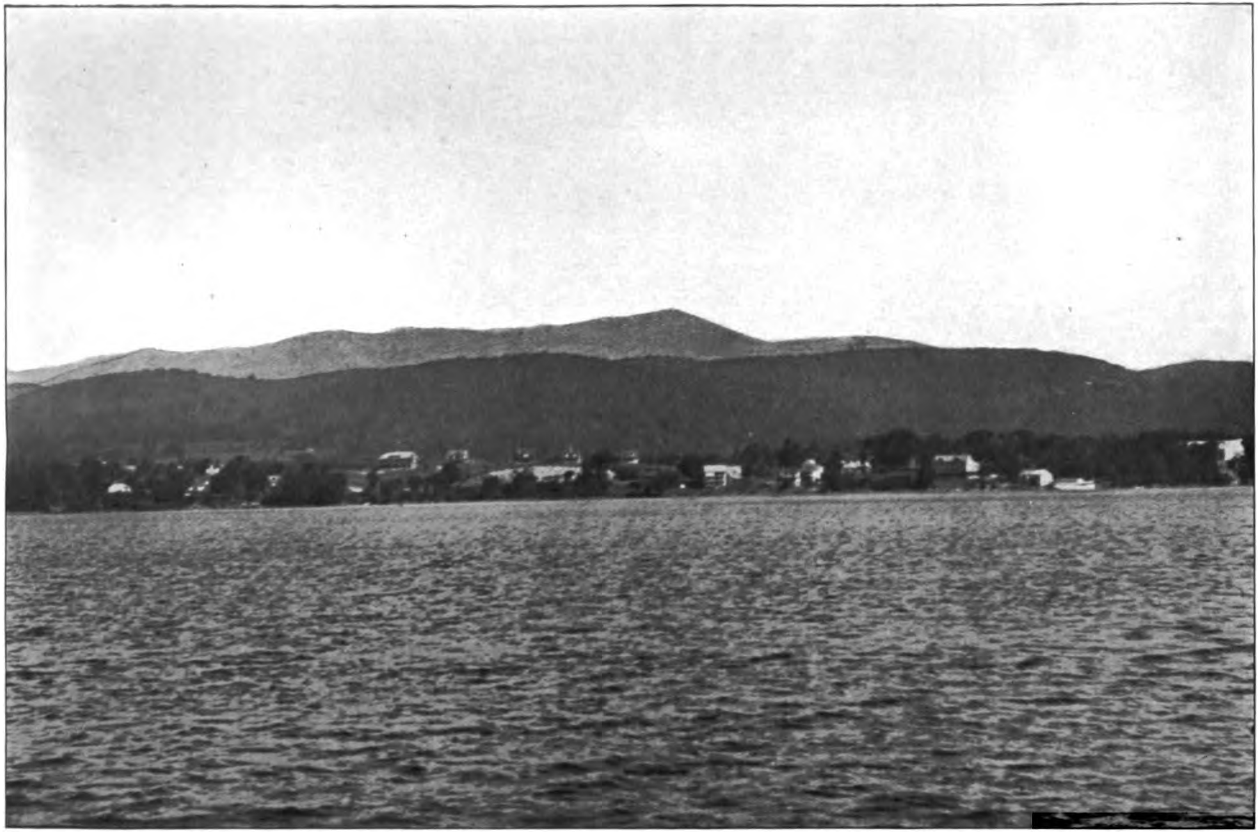
Grenville Series

General character. The Grenville series of strata, including possibly some contemporaneous igneous rocks, are considered to belong among the oldest known, or Archeozoic, rocks of the earth. These strata represent original shales, sandstones and limestones which have become thoroughly crystallized into various schists and gneisses, quartzites and crystalline limestone or marble. The stratification is usually rather distinctly preserved though not with its original sharpness. A more or less well-developed foliation is always parallel to the stratification.

Grenville rocks are not very prominent in the Schroon Lake quadrangle, the combined definitely known areas totaling not over 12 square miles. It is quite certain, however, that Grenville strata of great thickness once spread over not only the whole area of the quadrangle and the 10,000 square miles of the Adirondack region, but also over much of eastern Canada. They were, no doubt, mostly deposited under marine waters much like the typical sediments of later ages. Within the quadrangle no positive proof for great thickness has been obtained, but in other districts a thickness of at least several miles has been demonstrated. Regarding the lands from which the Grenville sediments were derived, and the floor upon which they were deposited, we know nothing at present. That organisms lived in the waters while Grenville deposition took place those many millions of years ago seems evident from the dissemination of graphite (crystallized carbon) through much of the limestone as well as through certain of the schists and gneisses.

A glance at the accompanying geologic map will show the very "patchy" distribution of the Grenville rocks, this being due to the fact that the original body of thick strata, which was the universal country rock of the quadrangle, has been badly broken up, lifted or tilted in masses great and small, more or less engulfed and, in some cases, injected or even partially assimilated by the great intrusive bodies of the region. The entire absence of Grenville strata from the anorthosite area is doubtless due to a laccolithic structure of the anorthosite whereby the Grenville was notably lifted or domed over the rising magma, and completely removed

Plate 3



W. J. Miller, photo, 1917

A view of the mountains looking northwest across Schroon lake and the village from Isola Bella. Blue ridge with Mount Hoffman, its highest point, in the distance. The Schroon Valley fault passes along the base of the nearer ridge.

by subsequent erosion. The later syenite-granite magma, however, had a much greater tendency to more or less intimately break up, penetrate, and even engulf the Grenville strata. All except possibly the few largest areas of the quadrangle may well be regarded as true inclusions in the syenite-granite series.

Since nearly all the various types of Grenville rocks below mentioned in the descriptions of the Grenville areas have been described in the writer's report on the *Geology of the North Creek Quadrangle*,[1] it seems needless to repeat the details here.

Description of Grenville areas. The rocks of the various Grenville areas are described somewhat in detail, in order to have on record the more important data which may possibly aid in working out at least the broader stratigraphic relations of the Adirondack Grenville series. The structural features of the Grenville are discussed in the chapter on Structural Geology. Dips and strikes are shown on the accompanying geologic map.

Minerva area. This is the largest area of the quadrangle (see map) and, although there are many excellent exposures, nevertheless they are not numerous enough to make it possible to gain anything like an accurate idea of the stratigraphy and structure of the area. The best exposures are north, northwest and west of Minerva. South and southeast of that village there are very few outcrops so that the southern boundary of the area is mostly rather uncertain. Practically all the Grenville rocks of the area show a northwest strike (see map).

The little hill just west of Minerva consists of well-bedded quartzitic, biotitic and hornblendic gneisses, all very typical of the usual Grenville series. Just back of the hotel a small mass of twisted crystalline limestone lies in contact with the granite there mapped.

On the steep hillside one-half of a mile farther west the rock is mostly hornblende gneiss, some with garnets, and with some bands of biotite gneiss and quartzite interbedded.

Northwest of Minerva, in and near the garnet mine, crystalline limestone associated with much red garnet and green pyroxene is closely involved with granite, this being separately mapped as mixed rocks. Just south of the mine there is a vertical ledge, nearly 100 feet high, of well-bedded granitic-looking gneiss, impure quartzite, and some limestone.

[1] N. Y. State Mus. Bul. 170.

On the hillside north of the road, from Calahan pond southeast for 1 mile, there are many fine exposures of crystalline limestone with some closely involved pyroxene and hornblende gneisses toward the north. Toward the south this limestone contains yellow quartz and graphite.

That portion of the area near the map edge from Calahan pond northward shows a number of fine exposures of crystalline limestone mostly containing graphite associated with some pyroxene and hornblende gneisses, and exhibiting local foldings or contortions. Just north of the small gabbro stock at the map edge the Grenville consists of hornblende, hornblende-garnet and pyroxene gneisses, and some quartzite.

A very fine outcrop of Grenville was observed a few rods west of the quadrangle boundary on the southern side of the small gabbro stock 1 mile southwest of Sherman pond, the ledge being clearly visible from the road. In a section fully 100 feet thick pyroxene gneiss and biotite gneiss and quartzite are beautifully stratified in thin beds. In the lower half of the section a dike of granite several feet thick has been intruded, both the dike and its foliation being perfectly parallel to the stratification of the Grenville.

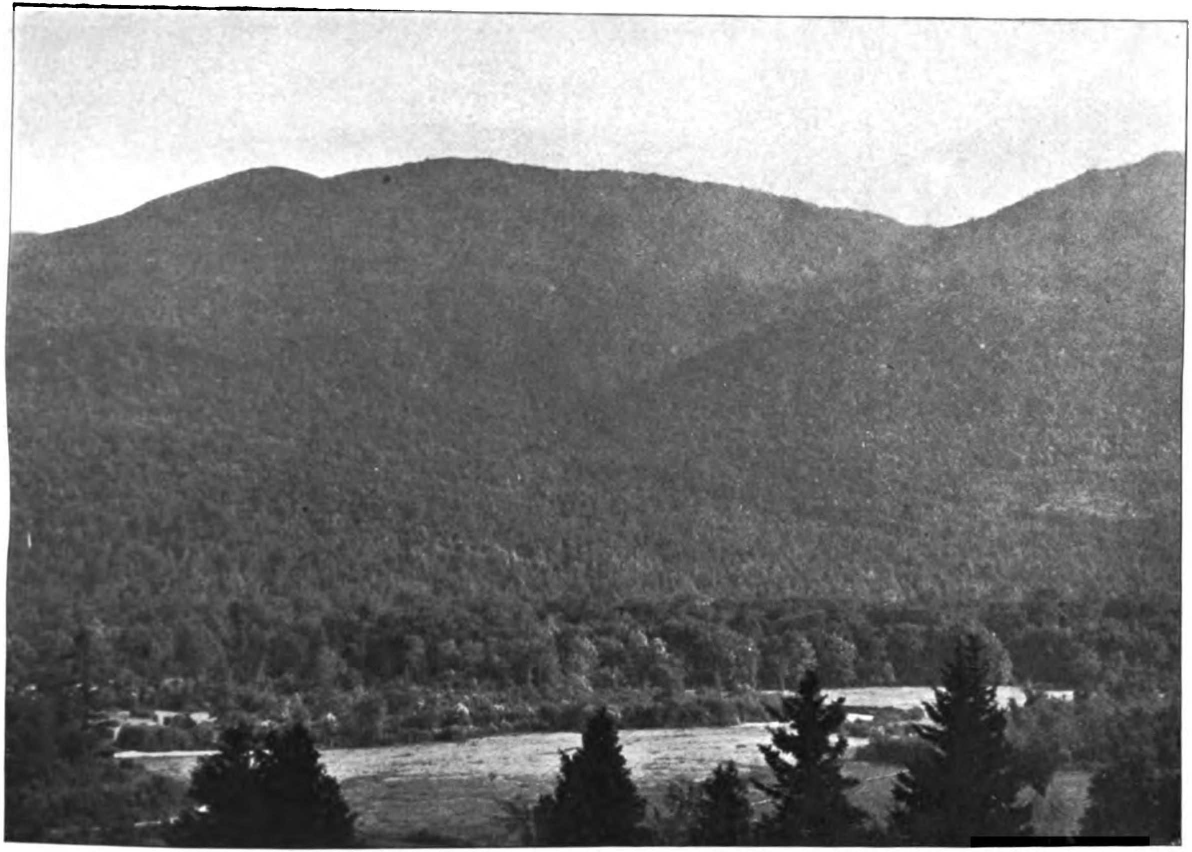
Most of the ridge 1 mile east of Calahan pond appears to be quartzite with hornblende and pyroxene gneisses and some limestone at its eastern base, and hornblende gneiss at its western base, but the outcrops are not very good. On and near the road 1 mile a little north of east of Minerva there are several ledges of rather coarse graphitic limestone associated with some thin-bedded, gray, rusty graphitic gneiss and quartzite.

Exposures showing contorted limestone with pyroxene and hornblende gneisses occur three-fifths of a mile west of the mouth of Kelso brook.

The hill 1 mile west of Irishtown consists of hornblende and biotite gneisses on the south side of the small gàbbro stock, and quartzite underlain by some limestone on the north side.

On the slope northwest of the hill just mentioned, several exposures of well-bedded hornblende-garnet gneiss, and one of limestone, were observed. From Falls brook northward the Grenville nearly all appears to be typical hornblende-garnet gneiss in good exposures. Limestone shows in a small exposure on the trail one-half of a mile northwest of Irishtown.

Plate 4



W. J. Miller, photo, 1917

The northern end of Blue ridge as seen from a point at the base of Saywood hill. The valley in the foreground, which is the bed of the extinct glacial lake Blue Ridge, lies at an altitude of 1200 feet and the mountain rises 2300 feet above it.

Olmstedville-Irishtown area. This area of Grenville is almost certainly connected, under the Pleistocene of Minerva stream valley, with the Minerva area.

In Olmstedville, by the stream one-fifth of a mile east of the mill, there is a big ledge of typical limestone. At the bridge just east of Olmstedville, limestone underlying hornblende gneiss forms a ledge 100 feet long. By and near the road one-third of a mile east of the bridge just mentioned, there are several outcrops, including hornblende gneiss, rusty mica quartzitic gneiss and limestone.

Two small outcrops of limestone occur by the road about a mile east of Olmstedville.

In a field 1⅓ miles northeast of Olmstedville, there is a large exposure of typical graphitic limestone with some small masses of rusty gneiss twisted into it. Nearby is an outcrop of hornblende gneiss.

Near the road one-half and three-fourths of a mile, respectively, southwest of the village, there are several small exposures of graphitic limestone with some small masses of closely involved pyroxene gneiss. The one nearest the village is weathered to a friable mass and is used for repairing roads.

Near the road corners one-half of a mile northwest of Olmstedville there are several outcrops of limestone, some containing graphite and green pyroxene and associated with hornblende gneiss. From this locality northward for a mile, by and near the road, there are other good exposures of similar rocks.

From one-half to 1 mile east-southeast of Irishtown there are interesting exposures of Grenville. Coming against the syenite on the south side (see map) there are several good exposures of limestone arranged along a strike N 70° W. Just within the syenite there is a long, narrow inclusion of quartzite. Where the limestone belt comes to the road, hornblende gneiss outcrops. Just north of the tongue of syenite there are large exposures of quartzite with a little associated limestone arranged along a N 70° W strike.

One mile north-northwest of Olmstedville, and extending from the road eastward for 200 yards, there are good outcrops of rusty biotite gneiss, hornblende gneiss and quartzite.

Along the road from one-half to 1 mile north of Irishtown, there are several exposures of hornblende gneiss (some garnetiferous) and a little associated limestone.

The tongue of Grenville which forms part of the mountain spur 1 mile north-northeast of Irishtown consists of hornblende and

hornblende-garnet gneisses with a little interbedded quartzite and biotite gneiss.

Catamount hill area. Catamount hill itself is a practically solid mass of well-bedded biotite-graphite schist or gneiss with some belts of quartzitic rock toward the summit.

At the old graphite mine by the road west of Catamount hill, the rock which was mined is a rusty looking biotite-graphite schist in very thin layers. Most of this rock, forming a belt 30 to 40 feet wide, contains tiny flakes of graphite, but one zone in it only a few feet wide is very rich in large flakes of graphite. In contact with this graphite-rich rock there is a narrow band of limestone containing green pyroxene and graphite.

Near the road one-fifth of a mile north of the mine there occurs a ledge of quartzitic to granitic looking gneiss with one two-foot wide band containing lenslike garnets up to an inch long.

Adirondack village area. This small area shows only a few outcrops. A small exposure of limestone just east of the village contains some graphite and green pyroxene. By the road one-half of a mile south of the village, there occurs a ledge of bedded hornblende-biotite gneiss. At the southern end of the area there are several good exposures of variable rocks, mostly hornblende gneiss, biotite gneiss and pyroxene-garnet gneiss. These are mostly well bedded but shot through with some coarse granite. No outcrops occur along, or just east of, the map boundary here, but, judging by Doctor Ogilvie's Paradox lake map, this Adirondack village area of Grenville probably extends across the boundary.

Areas on the shores of Schroon Lake. At the southern end of Isola Bella there is a mass of limestone 20 feet long, really an inclusion in the granite. This limestone contains pyroxene, quartz and some graphite.

At Grove Point there are two exposures by the lake shore, one being limestone with bunches and strips of green pyroxene gneiss kneaded into the mass, and the other pyroxenic and hornblendic gneisses with a little associated limestone.

A few rods south of the Grove Point Grenville, syenite contains a long, narrow inclusion of Grenville limestone.

On the lake shore one-half of a mile east of South Schroon, limestone with patches of green pyroxene gneiss twisted into it shows in a good exposure.

Areas northwest of Schroon Lake village. The small lens-shaped area shown on the map 1 mile northwest of the village con-

sists of interbedded quartzite (some garnetiferous), quartz-pyroxene gneiss, and quartz-feldspar gneiss with several thin layers of limestone containing green pyroxene.

The area just east of North pond shows a number of good exposures of well-bedded hornblende-garnet gneiss and hornblende gneiss with one two-foot thick layer of limestone in the hornblende gneiss. Near the western corner of the area there are many large reddish brown garnets up to 4 or 5 inches in diameter, but without hornblende rims as is often the case with such large garnets in the Grenville hornblende-garnet gneiss elsewhere in the Adirondacks.

Other areas of Grenville. In the small area on the west face of Wilson mountain, pyroxenic, hornblendic and quartzitic gneisses are well exposed, some of these being locally contorted. Along the eastern side of this area the Grenville rocks are more or less intimately charged with granite.

At the western end of the area just southwest of Oliver pond there is a big exposure of hornblende-garnet gneiss interstratified with thin-bedded, fine grained, pinkish gray, quartz-biotite schist. A few rods farther east there occurs a ledge of limestone containing green pyroxene, quartz and a little graphite. Toward the eastern end of the area the rock is hornblende-garnet gneiss.

A small lenslike inclusion of hornblende-garnet gneiss with garnets up to an inch across occurs in the granite one-half of a mile west of Oliver pond.

One mile northeast of Loch Muller,[1] in the small area mapped, there is a single large outcrop of hornblende gneiss, somewhat garnetiferous.

On the southern slope of Hayes mountain, three-fourths of a mile from its summit, a small lenslike body of typical hornblende-garnet gneiss with garnets up to an inch across occurs as an inclusion in granite. A similar small inclusion occurs in the syenite 2 miles north-northwest of Irishtown, and still another in granite 1¼ miles west-southwest of the summit of Hayes mountain.

[1] This is the place printed on the map accompanying this bulletin, but since the map was printed the post office has been moved 2 miles to the northwest to Warren's hotel.

Some interesting exposures occur in the small area 1½ miles northwest of the summit of Hayes mountain. In the old stone quarry the rock is greenish limestone containing serpentinized green pyroxene and some graphite. This is associated with some hornblendic and quartzitic gneisses. Similar rocks outcrop on the west bank of the stream, but there the pyroxene is less serpentinized. Undoubtedly this mass of Grenville is a fairly large inclusion in the granite which outcrops close by on all sides.

In the Hewitt Pond brook area there are several good outcrops of Grenville hornblende gneiss and hornblende-garnet gneiss.

A conspicuous lenslike mappable inclusion of hornblendic and quartzitic well-bedded gneisses occurs in the granite 1¼ miles east-southeast of Boreas river.

Still other masses of Grenville occur within the quadrangle, but these are so closely associated with other rocks that they are mapped and described as "mixed rocks."

Anorthosite Series

General considerations. Recently the writer has published a rather elaborate paper[1] on the whole problem of the age, relations, and origin of the Adirondack anorthosite. The interested reader is referred to that paper for much more material than is presented in this bulletin. Some years ago, Professor Cushing, in his report[2] on the *Geology of the Long Lake Quadrangle,* presented evidence to show that the anorthosite is a great intrusive body distinctly younger than the great syenite-granite series of the Adirondacks. The writer heartily agrees with this view, and in his own field studies, particularly in the Lake Placid and Schroon Lake quadrangles, he has found much more evidence in support of Cushing's view. Recently, however, Dr N. L. Bowen[3] has offered quite a different explanation of the origin and relations of the anorthosite. His hypothesis and the writer's objections to it are briefly stated below, but a fuller criticism is presented in the paper above cited.

The anorthosite occupies a largely unbroken area of about 1200 square miles of the central-eastern Adirondack region. It is prominently developed with nearly all its facies in the Schroon Lake

[1] Geol. Soc. Amer. Bul. 29 No. 4, 1918, p. 399–462.
[2] N Y. State Mus. Bul 115, p. 479–82. 1907.
[3] Jour. Geol., 25:209–43. 1917.

quadrangle where, as a result of its careful study, important light has been thrown upon the age, relations, structure, and origin of the great anorthosite body. Most of the northeastern half of the quadrangle, or an area of over 80 square miles, is occupied by anorthosite to the exclusion of all other formations except Pleistocene deposits and a few small basic dikes.

Marcy type of the anorthosite. By far the most abundant general facies of the rock may be called Marcy anorthosite because of its great exposures on Mount Marcy in the quadrangle next to the north. The most typical portions of the Marcy anorthosite are coarse grained, light to dark bluish gray, and consist largely of basic plagioclase feldspar, mainly labradorite. The dark bluish gray labradorite crystals usually vary in length from a fraction of an inch to several inches, crystals about an inch long being very common. Among other places, labradorites from 5 inches to 1 foot long were observed on the western of the three Peaked hills, and on the ridge 1 mile north-northwest of Blue Ridge village. Only occasionally do these labradorites exhibit the play of colors so characteristic of this species of feldspar. Twinning striations are often evident to the naked eye on the cleavage faces.

Accessory minerals visible to the naked eye are large individuals of pyroxene and hornblende, and small individuals of biotite, ilmenite, pyrite, garnet, and more rarely chalcopyrite or pyrrhotite. These accessory minerals ordinarily constitute 5 to 10 per cent of the typical coarse anorthosite, but there are local developments of the rock which are made up almost entirely of plagioclase, and still others, rather abundantly developed as zones, bands and irregular masses, which contain from 10 to 25 or more per cent dark minerals, these last named types being really anorthosite-gabbros. Such gabbroid facies are more fully described below.

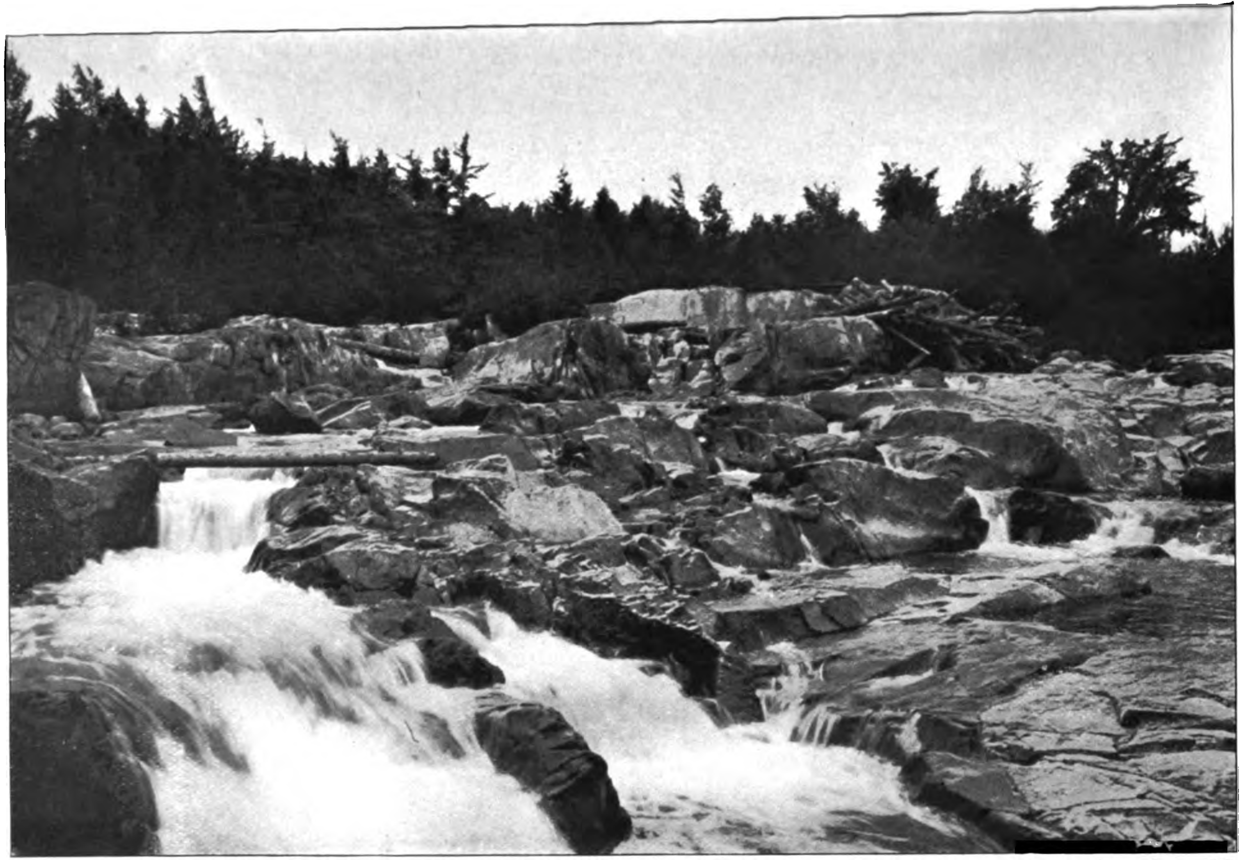
An important facies of the anorthosite is one in which the dark labradorites, from a few millimeters to an inch or more across, stand out conspicuously in a distinctly granulated groundmass of feldspar. The granulated material varies from light gray to pale greenish gray. It is very evident that the large labradorites are roughly rounded uncrushed cores of what were considerably larger individuals before the rock was subjected to the process of granulation. All degrees of granulation are exhibited to extreme cases where the rock has been so thoroughly granulated that few, if any, labradorite cores remain.

Much of the typical Marcy anorthosite is devoid of foliation, though in some local zones of almost perfectly pure plagioclase rock there is a notable tendency for the feldspars to show a crude parallelism (plate 6). The more gabbroid facies of the rock, however, often exhibit a fair to well-defined foliation accentuated by the crudely parallel arrangement of the dark minerals.

In thin section, with a low power of the microscope, the larger labradorites are usually seen to be filled more or less with myriads of very dark dustlike particles, probably ilmenite. The minerals contained in several thin sections of the Marcy anorthosite are shown in table 1 below.

Chilled border facies of the anorthorsite (Whiteface anorthosite). Around the borders of the great body of Adirondack anorthosite, and in some places a number of miles within it, there is quite generally a notable development of white or very light-gray labradorite and an increase in the femic minerals causing such rocks to be anorthosite-gabbro or even gabbro. Such rocks, well developed in the Schroon Lake quadrangle, are almost invariably finer grained and lighter colored than the typical Marcy anorthosite, though in some localities a few large, scattering labradorite individuals occur. A foliated structure is generally evident.

Although they are more or less variable in general appearance and composition, the writer has proposed that these border phases of the anorthosite be classed as Whiteface anorthosite, a name given by Professor Kemp to the type which occurs abundantly on Mount Whiteface near Lake Placid. At the summit of Mount Whiteface the rock is medium grained and consists of white plagioclase (chiefly labradorite) with 10 to 15 per cent of dark minerals scattered through the mass parallel to a crude foliated structure. Such rock, which is quite typical of the Schroon Lake quadrangle Whiteface anorthosite, stands out in marked contrast against the typical Marcy anorthosite which is not so gabbroid, very coarse grained, light to dark bluish gray, and generally not so well foliated. More exceptionally the Whiteface anorthosite is nearly pure white, being quite free from femic minerals. Much of the rock, however, is locally richer in dark minerals, which may constitute 15 to 30 per cent of the whole. The minerals other than the feldspar are practically the same as in the Marcy anorthosite. Table 1 gives a good idea of the mineral content of the Whiteface anorthosite of the quadrangle.



W. J. Miller, photo, 1917

Marcy anorthosite in the bed of The Branch brook one-third of a mile west of Blue Ridge village

Table 1 Thin sections of anorthosite

	Slide no.	Field no.	Labradorite	Andesine	Pyrox. (Mono.)	Diallage	Quartz	Hornblende	Hypersthene	Biotite	Garnet	Magnetite	Pyrite	Limonite	Apatite	Zircon	Titanite	Hemalite	Calcite (Sec.)	Chlorite
Marcy An.	20	11 k 1	99	...	½	...	...	...	...	...	...	½	...	...	little	...	...	...	...	...
	23	14 d 3	77	...	12	2	1½	...	...	...	5	2	½	...	...	...	...	...	...	.
	24	15 i 6	70	...	...	...	1	1	27	...	...	1	little	...	...	...	...	...	...	...
Whiteface anorthosite	10	4 f 8	99	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
	11	5 d 11	75	10	...	12	...	1½	...	...	...	1½	...	...	little	little	...	...	...	...
	12	6 l 2	92	...	...	4	...	2	...	1	⅓	...	little	...	...	little	little	...	...	...
	13	7 e 12	68	...	...	5	10	5	...	½	10	1	little	...	½	little	...	...	...	...
	14	7 e 9	85	...	2½	...	...	12	...	...	...	...	...	...	little	little	...	¼	...	...
	15	7 h 1	81	...	5	...	2	3	...	...	5	1½	¼	...	little	little	...	...	2	...
	16	7 g 1	68	...	10	2½	8	8	...	...	...	3	½	...	...	...	...	...	...	...
	17	8 m 6	88	...	...	...	...	½	½	...	9	1½	½	...	little	...	little	...	...	...
	18	9 e 5	78	...	4	...	10	4	...	...	1½	1½	½	½	...	...	little	...	...	...
	19	10 l 1	98	...	...	...	...	...	...	...	1	¼	little	...	...	little	little	...	...	...
	21	13 g 2	94	...	...	...	...	...	...	...	½	½	...	little	...	...	...	...	...	5
	22	14 c 4	38	...	35	...	15	little	...	...	10	1½	little	...	½	...	...	...	...	...
	37	8 f 25	67	10	14	...	...	8	...	...	...	...	...	...	½	little	½	...	...	...

No. 20, three-fourths of a mile southeast of summit of Hoffman mountain; no. 23, by the road 1 mile northeast of Boreas river; no. 24, by the stream 1 mile east-southeast of summit of Ragged mountain; no. 10, 1 mile southeast of summit of Oliver hill; no. 11, 1½ miles a little west of north of Irishtown; no. 12, lake shore just north of Grove Point; nos. 13 and 14, one-half of a mile west-northwest of Bigsby hill; no. 15, by road at Loch Muller; no. 16, one-third of a mile west of Loch Muller; no. 17, one-half of a mile south-southeast of summit of Severance hill; no. 18, top of Hayes mountain; no. 19, by the brook southwest of Smith hill; no. 21, near western summit of Sand Pond mountain; no. 22, near cross-roads at Boreas river; no. 37, southern brow of Cobble hill.

No. 17 of table 1 exhibits very fine reaction rims as follows: (1) magnetite with rims of garnet; (2) pyrite with rims of garnet; and (3) magnetite with successive rims of hypersthene and garnet.

Both the Marcy and Whiteface types of anorthosite are quite certainly differentiation phases of the same cooling magma, the latter representing a chilled border or marginal portion. The one type grades into the other, and nowhere has one been found definitely to intrude the other.

Special descriptions of Whiteface anorthosite occurrences. In the Boreas river area the Whiteface anorthosite is mostly rather uniformly moderately gabbroid and foliated with scattering bluish labradorites, but some local variations from this composition and structure were observed. Near the cross-roads at Boreas river (no. 22 of table 1) a ledge is unusually rich in pyroxene and quartz.

In the eastern portion of the Sand Pond mountain area the rock is nearly white and free from femic minerals, nonfoliated, and with only a few scattering blue labradorites (no. 21 of table 1). The rock of the western portion of the area strongly suggests Marcy anorthosite and grades into it. It is light gray and nonfoliated with 10 to 20 per cent dark minerals and garnets and many blue labradorites.

The Severance-Smith hill area, the largest shown on the map, comprises mostly rather uniform, very typical, Whiteface anorthosite (nos. 17 and 19 of table 1). At the extreme southern end it contains an admixture of Grenville.

In the large area southwest of Bailey hill the Whiteface anorthosite is mostly very typical. By the old road on the west side there are some rather gabbroid, garnetiferous, foliated zones, and in the eastern portion there are locally developed masses with many garnets and some scattering blue labradorites.

A large ledge of Whiteface anorthosite at Loch Muller is exceedingly variable as regards both content of femic minerals and foliation. It contains some bluish labradorites and scattering garnets (no. 15, table 1). One-third of a mile farther west in the same area the rock is distinctly gabbroid and foliated and carries 8 or 10 per cent of quartz (no. 16, table 1). In the western part of the area the rock is very typical Whiteface anorthosite.

The long, narrow area south of Hewitt road shows Whiteface anorthosite varying from light-colored, moderately gneissoid to dark-colored, gabbroid, very gneissoid facies.

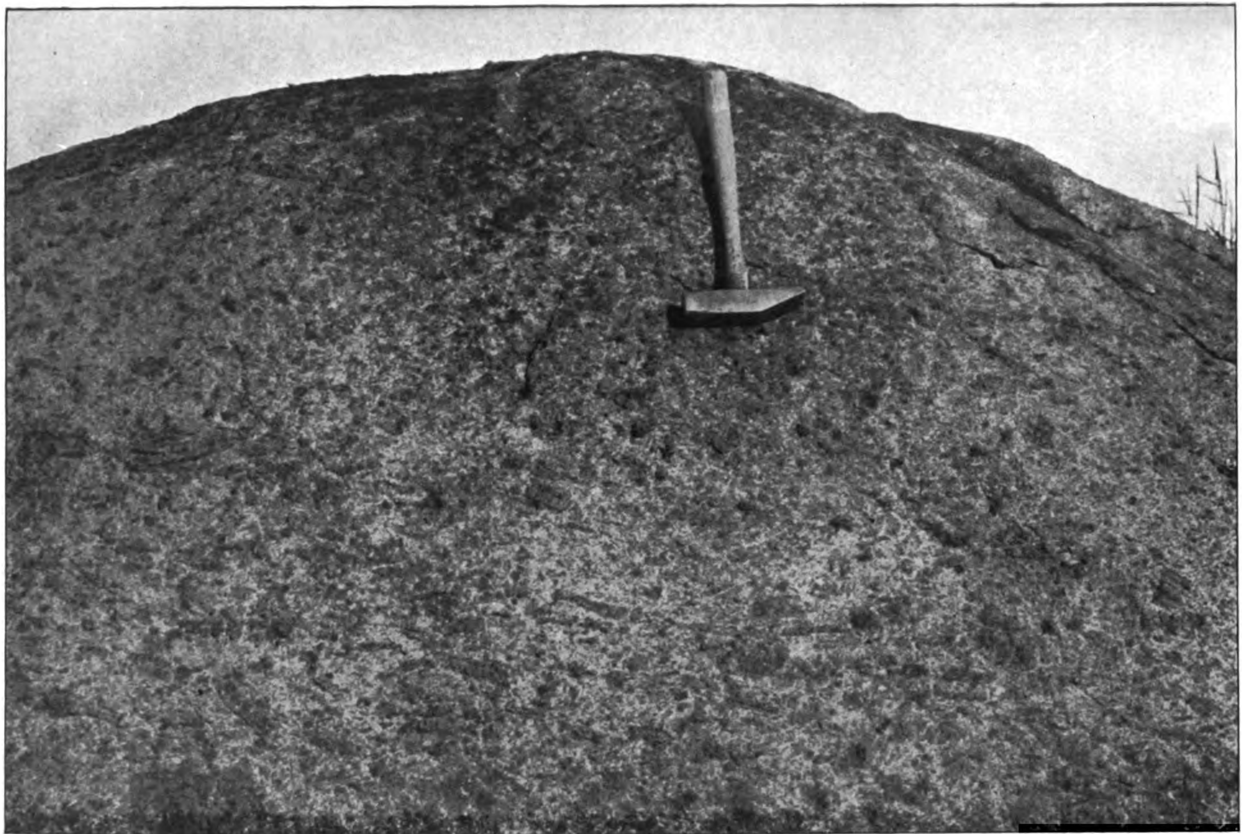
The rocks of the area west of Bigsby hill exhibit many local variations from typical anorthosite to very gabbroid, gneissoid anorthosite. In some ledges quartz is visible to the naked eye. Nos. 13 and 14 of table 1 are from this area.

A big ledge of gabbroid, very gneissoid Whiteface anorthosite (no. 11 of table 1) in the small area 1½ miles a little west of north of Irishtown is intimately associated with Grenville hornblende-garnet gneiss, the latter commonly occurring as distinct strips or lenslike inclusions in the anorthosite.

The remaining small areas of Whiteface anorthosite require no special description here.

Variable composition and structure of the anorthosite and its significance. *General statements.* Contrary to Bowen's statement that "anorthosites are made up almost exclusively of the single mineral plagioclase," the writer's experience in the field has made

Plate 6



W. J. Miller, photo, 1917

Near view of part of a boulder of Marcy anorthosite in a field three-fourths of a mile northwest of Pat pond. Foliation, due to crude parallelism of large crystals of labradorite, is very distinct in the lower part but not in the upper.

it clear that the Adirondack anorthosite is by no means an almost perfectly homogeneous mass of plagioclase. The main bulk of the Marcy anorthosite contains at least 5 to 10 per cent of minerals other than plagioclase. Portions with about 10 per cent are common, and in many places there are 10 to 20 per cent, or even more, of dark minerals. It is also true that some portions of the great mass contain less than 5 per cent of femic constituents. Conservatively estimated, the average Marcy anorthosite carries fully 10 per cent of minerals other than plagioclase.

In the writer's work in both the Lake Placid and Schroon Lake quadrangles, many observations have been made of anorthosite-gabbro and more typical anorthosite exhibiting perfect gradations from one into the other. Such gabbroid facies exist locally throughout the body of Marcy anorthosite, in many places as rather distinct zones or belts a few feet or rods wide, and in other places on much larger scales. Many other gabbroid portions are much more irregular in shape, and not so distinctly separated from the purer Marcy anorthosite.

The anorthosite-gabbro very commonly, and the typical Marcy anorthosite less commonly, locally exhibit more or less well-developed foliation with exceedingly variable strikes. Marked variations in degree of foliation often occur in single ledges. It is also important to note that granulation, so prevalent throughout the anorthosite body, shows many extreme variations, often in single outcrops.

Another variation of the anorthosite from a pure plagioclase rock consists in the dustlike (schillerization) inclusions of a dark mineral, probably ilmenite, in the labradorite. These are so numerous as to cause most of the labradorites to have a dark bluish gray color. Thus even the plagioclase crystals are not pure lime-soda feldspar.

Finally in this connection, attention should be called to the presence of a very appreciable amount of potash in the typical Marcy anorthosite, as shown in an analysis made for Professor Kemp. Whether this potash exists in regular potash-feldspar form, or is part of the labradorite proper, it is additional proof that the anorthosite is not a practically pure mass of lime-soda feldspar.

Some examples of variations of Marcy anorthosite. Near the top of the hill 1 mile a little to the west of north of Blue Ridge village, the following variations across the strike from south are finely exhibited: first, there is typical Marcy anorthosite; then, a band 2 feet wide of gneissoid, moderately coarse-grained, gabbroid

anorthosite with a few labradorite phenocrysts; then, a belt 40 feet wide of less coarse-grained anorthosite with a few labradorite phenocrysts and scarcely any femic minerals; next, a belt 35 feet wide of very coarse-grained, gabbroid anorthosite with pyroxene and labradorite crystals from 6 inches to 1 foot each in length. None of these belts or zones is very sharply separated, though in some cases the change from one into the other takes place within a few inches.

At the rapids of Boreas river, just before the stream enters the Brace dam reservoir, a big ledge of typical Marcy anorthosite with very few femic minerals contains a very irregular shaped mass of highly femic and garnetiferous anorthosite some 30 feet long with a maximum width of 10 feet. Except for the 20 to 30 per cent of dark minerals, this femic anorthosite is much like the inclosing anorthosite. Boundaries against the typical anorthosite are not sharp, but the complete transition takes place within 5 or 6 inches. The femic rock is nonfoliated, but the typical Marcy anorthosite on one side of it has most of its labradorites (1 to 2 inches long) arranged parallel to the contact with the femic rock. This parallelism is most evident close to the contact and not at all noticeable 6 or 8 feet out.

By the road three-fourths of a mile east of where it crosses Boreas river, a 50-foot exposure of typical Marcy anorthosite, with less than 5 per cent femic constituents and with many labradorites an inch long, exhibits very distinct foliation due to parallelism of the labradorites. This rock grades into typical nonfoliated anorthosite of the adjacent exposure.

By the same road above mentioned, but one-third of a mile farther east, a 50-foot ledge of anorthosite with 10 or 15 per cent femic minerals contains several distinctly foliated zones not sharply separated from the rest of the rock.

In a ledge of typical Marcy anorthosite on the middle-southern slope of Saywood hill, a distinctly foliated zone occurs in contact with nonfoliated anorthosite on either side.

From Saywood hill to Clear Pond mountain there are large scale variations represented chiefly by typical, nongabbroid, mostly nonfoliated, Marcy anorthosite with some labradorites up to 3 inches long on Saywood hill; very coarse, rather gabbroid, nonfoliated anorthosite containing labradorites up to 6 or 7 inches long and 10 to 20 per cent femic minerals on Clear Pond mountain; and many fine exposures of more typical Marcy anorthosite with usually 10 to 15 per cent femic minerals and little foliation.

In the whole area from Blue Ridge mountain eastward to the map limit, there are many excellent exposures of remarkably uniform, very typical Marcy anorthosite, there being few gabbroid or foliated variations in this large area.

Where the road crosses the Branch brook a ledge of typical Marcy anorthosite contains an irregular gabbroid mass about 2 feet wide without sharp boundaries against the inclosing rock.

Variations similar to those just described were observed in many other places, but enough have been described to illustrate the nature of the variability of the anorthosite.

Significance of the composition and variations of the Marcy anorthosite. According to Bowen, " anorthosites are made up almost exclusively of the single mineral plagioclase " and therefore " the conception of the mutual solution on minerals in the magma and the lowering of temperatures consequent thereon is no longer applicable." But, in view of the facts above presented which show that the anorthosite averages fully 10 per cent femic minerals visible to the naked eye; that the labradorites carry myriads of tiny inclusions of a dark mineral; and that the anorthosite contains a notable percentage of potash, is the mutual solution theory necessarily precluded? Have we any proof that a rock with such a quantity and variety of constituents other than plagioclase could not have been, largely at least, molten as such? Is it safe to argue from experiments on small amounts of rather pure melts under ordinary laboratory conditions that a rock like the Adirondack anorthosite could not have existed as a true magma? Bowen says that " a rock containing 10 per cent diopside (and 90 per cent plagioclase) could have had a maximum of 35 per cent liquid " in an artificial melt, and that in a natural melt " the probability is that the amount of liquid would be relatively somewhat larger on account of the presence of orthoclase in the liquid." But the Adirondack anorthosite would have formed a melt of notably more complicated composition than an artificial melt with 10 per cent diopside, and this *under deep-seated geologic conditions.* Is it safe to say, therefore, that such a melt may not have been a true magma with a high percentage of liquid? Furthermore, allowance should be made for various agencies well within the earth, particularly dissolved vapors the escape of which pressure tends to prevent, and which tend to increase fluidity.

Since the foliation of the anorthosite is essentially a magmatic flow-structure, it shows that, at the very least, large portions of the

body of anorthosite once possessed fluidity enough to permit distinct magmatic currents or movements. The significance of the foliation is thus an important consideration. Even the typical Marcy anorthosite, almost entirely free from femic minerals, not rarely exhibits a magmatic flow-structure foliation (plate 6), the labradorite crystals having been strung out into crude parallelism in a yet molten portion of the rock. Not only was this interstitial liquid in sufficient quantity to permit the development of distinct magmatic flowage, but it was essentially *molten plagioclase*. It could have been nothing else. Hence we here have evidence directly opposed to Bowen's statement that the anorthosite was never at a temperature sufficiently high to melt plagioclase. It is not argued, however, that the anorthosite as such necessarily was intruded in the form of a true magma to its present position, having been differentiated at a much lower level. Rather, it is probable that a gabbroid magma was the original intrusive which, either during the process of intrusion or after the magma came nearly to rest, or both, differentiated to give rise to the anorthosite which was then, in considerable part at least, really molten. This matter is more fully discussed below.

Though the writer believes the anorthosite as such to have been molten to a very considerable degree at least, it is by no means necessary to assume that it was ever completely molten with a high degree of fluidity, or even only a moderate degree of viscosity. None of the field facts, however, necessarily preclude the hypothesis that the whole mass of the anorthosite may once have been completely molten, but without a high degree of fluidity.

Before leaving this consideration of the significance of the variability of the anorthosite, emphasis should be placed upon the fact that, in many places, its mass shows unmistakable evidence of having differentiation phases of anorthosite-gabbro or even gabbro, while there is no positive evidence for its differentiation into syenite or granite as should be the case according to Bowen's hypothesis.

Relation of Whiteface and Marcy types of anorthosite. In the Schroon Lake quadrangle as elsewhere, it is clear that the Whiteface anorthosite is a gabbroid border facies of the Marcy anorthosite with perfect gradations from one into the other, and with no evidence that syenite or granite was ever developed as a rock intermediate between the border phase and the true anorthosite as required by Bowen's hypothesis. Though it has been notably cut into, and partly assimilated by the syenite-granite body, a glance at

the geologic map shows beyond question that this Whiteface anorthosite was formerly a continuous border phase of the Marcy anorthosite which latter occupies the whole northeastern one-third of the quadrangle. Three large bodies of the Whiteface anorthosite still lie against the Marcy anorthosite in their original positions. There is strong evidence that this border phase was formerly at least 7 or 8 miles wide because, within that distance out from the Marcy anorthosite, many smaller widely scattered masses of the Whiteface rock occur as inclusions in the syenite-granite series all the way across the quadrangle. In other words, only remnants of the original border rock now occur. Further, since this border rock is notably finer grained than the Marcy anorthosite, it is very reasonable to interpret it as a chilled gabbroid border phase comparable in position and origin to Cushing's Long Lake border phase of the anorthosite, though of lighter color and usually not so gabbroid. The Schroon Lake quadrangle Whiteface anorthosite commonly carries 10 to 20 per cent dark minerals, but it is very variable, some phases containing only 5 per cent or even less, and some more than 20 per cent.

There is strong evidence that the chilled gabbroid border phase developed not only as an *outer* limit but also as an *upper* limit which formerly existed as a cover resting directly upon the whole great mass of anorthosite. Thus, as already pointed out in the writer's Lake Placid report, the Whiteface anorthosite of that area does not exist merely as a definite fringe around the outer margin of the Marcy anorthosite. Whiteface anorthosite there occurs fully 14 or 15 miles within the present border of the anorthosite area, and inclusions in the syenite-granite series outside the general anorthosite area show that the Whiteface anorthosite formerly extended at least a few miles farther out than the present boundary. One area of Marcy anorthosite, 12 miles long within the Lake Placid quadrangle and extending an unknown distance into the Ausable quadrangle, is flanked on either side by Whiteface anorthosite. It is hard to resist the suggestion that the Whiteface rock formerly covered this whole mass of Marcy anorthosite. There is thus a distinct difficulty in the way of considering this Whiteface anorthosite as merely an outer border facies. If we do regard it as merely an outer facies, we are forced to conclude that it is exceedingly thick, that is to say fully 10 or 15 miles, the width of the area containing Whiteface anorthosite representing practically the thickness of the border facies. This is scarcely conceivable.

The Schroon Lake quadrangle yields similar evidence since, as

above pointed out, the border facies (Whiteface type) there formerly extended fully 7 or 8 miles out beyond the present margin of the Marcy anorthosite as indicated by numerous inclusions in the syenite-granite series. In this connection, a very interesting inclusion of fragments of very typical Marcy anorthosite in the granite of Wilson mountain, over 6 miles out from the present border of that type of anorthosite, may be reasonably interpreted as Marcy anorthosite caught up in the granite magma at a lower level (below the Whiteface anorthosite cover) and carried upward to the present position (see figure 1). In any case it is certain that Marcy anorthosite existed that far out.

Within the Schroon Lake quadrangle no Whiteface anorthosite was found within the large area of Marcy anorthosite, it apparently all having been removed by erosion. Unless definite areas of the basic chilled border facies are found far within the great anorthosite area, positive proof that such a border once existed as a cover over the whole will be wanting. But such a cover, if once universally present, would show few, if any, remains far within the anorthosite area because of the widespread and deep erosion to which the region has been subjected.

In short, the evidence from the outer portions of the great Adirondack anorthosite body strongly supports the view that a chilled gabbroid border facies should be regarded as having formerly existed as a cover resting upon the whole mass of Marcy anorthosite. The evidence from the interior is negative, but nothing in the field is opposed to the conception of a former universal cover. But this does not preclude Cushing's conception of an outer chilled border of the anorthosite, provided we regard the anorthosite as a great laccolithic intrusive body (see figure 2) over all of which a border facies developed as an upper limit, and at the margins of which a border facies developed at the same time as an outer limit. The writer therefore agrees with Cushing that the area of anorthosite shown on the state geologic map shows practically "the original size of the mass at the depth represented by the present erosion surface," and that the anorthosite can not extend out to, or even close to, the margins of the whole Adirondack region.

According to Bowen, the femic constituents of a great gabbroid magma, as wide as the Adirondack region, first separated (or sank) by gravity, while the plagioclase crystals (then in the form of basic bytownite) remained practically suspended. At a later stage, when the liquid became light enough, plagioclase crystals (then in

the form of labradorite) accumulated by sinking, thus giving rise to the mass of the anorthosite, leaving the overlying liquid of such composition as to yield syenite or granite. In his first paper, Bowen does not consider the development of a chilled border of the Adirondack anorthosite. In his second paper, by way of reply to Cushing, he modifies his idea of the stratiform arrangement of the igneous complex by considering the development of a "gabbroid chilled upper portion of a laccolithic mass extending far beyond the limits of the present exposure." Directly under the chilled border, according to Bowen, the great body of syenite-granite developed; still lower down the typical anorthosite formed; and at the bottom, pyroxenite and gabbro.

Since the evidence above presented shows that the great body of Adirondack anorthosite has a chilled gabbroid border which can not possibly extend far out beyond the present exposure of the anorthosite, and evidence below presented is distinctly against existence of syenite or granite formed as a differentiate between the border facies and the typical anorthosite, it is clear that Bowen's hypothesis of the origin of the anorthosite by the settling of plagioclase crystals is untenable. There simply is nothing from which they could have settled. The writer believes, therefore, that it is out of the question to interpret the Adirondack igneous complex as even in a general way a "sheetlike mass with syenite above and anorthosite below" as required by Bowen's hypothesis.

Relation of the syenite-granite to the Whiteface anorthosite. According to Bowen, the syenite-granite and anorthosite are not distinctly separate intrusives, but both formed as differentiates from a single great body of intruded gabbroid magma. Cushing and the writer both believe the syenite-granite series to be distinctly later, and the writer has found abundant evidence in support of this view in both the Lake Placid and Schroon Lake quadrangles.

For the Long Lake quadrangle Cushing says[1]: "The field evidence seems clear that the anorthosite had solidified, with a chilled border, and had then been attacked from the side by a mass of molten syenite, which in places cut deeply into it." With this statement the writer agrees, but he would further say that both granite and syenite of the syenite-granite series have, in certain other districts like the Lake Placid and Schroon Lake quadrangles, not only cut deeply into, but also they have either largely cut out

[1] Jour. Geol., 25:507. 1917.

or more or less assimilated, the border facies of the anorthosite. Detailed field evidence in support of this view is presented below.

Cushing maintains that the chilled border is fatal to Bowen's conception that molten overlying syenite may have been faulted down against solid anorthosite so that it could have laterally attacked the anorthosite, thus accounting for the intrusive features including the syenite dikes. Much detailed field work by the writer shows that the chilled border (Whiteface anorthosite) grades directly into the typical anorthosite, and that there is no reason to think that the syenite-granite series developed between the chilled border and the typical Marcy anorthosite. Even if we assume, what has not been found in the field, that some such syenite or granite exists as a rock intermediate between the chilled border and the typical anorthosite, it is most unreasonable to suppose that the chilled border would, in some places, grade first into the syenite or granite and then into the Marcy anorthosite. Either one of these might be the case, but not both.

Bowen suggests that the syenite-granite may have developed between the chilled border and the Marcy anorthosite, and then have been reintruded through the chilled border. But how can we possibly imagine such a vast bulk of syenite-granite to have been so largely reintruded that not any of it has been discovered in its supposedly original position? Also how can we imagine the reintrusion of such a tremendous volume of syenite-granite through the chilled border facies, leaving this latter as a definite fringe about, and grading into, the Marcy anorthosite for so many miles?

Dikes of syenite and granite in anorthosite. Some years ago, in his report on the *Geology of the Long Lake Quadrangle,*[1] Cushing showed that several narrow well-defined dikes of syenite there cut the typical Marcy anorthosite, one of these dikes being several miles within the border of the great anorthosite body. He also states that one of the small outlying masses of anorthosite is "definitely cut by syenite which sends dikes into it."

As a result of the surveys of both the Lake Placid and Schroon Lake quadrangles by the writer, various excellent examples of dikes and broad tongues of syenite and granite cutting anorthosite have come to light. A number of fine examples of such dikes are described in the report on the *Geology of the Lake Placid Quadrangle.*

[1] N. Y. State Mus. Bul. 115, p. 480–84. 1907.

In the Schroon Lake quadrangle a number of clearly defined dikes of granitic syenite and granite were observed in the anorthosite. One of these is well shown by the road 1½ miles west of Boreas river where a dike of granite 5 feet wide cuts rather femic Whiteface anorthosite without very sharp contacts. Another is a dike of typical pinkish gray granite 25 feet wide 1 mile west of the western summit of Sand Pond mountain. It sharply cuts Whiteface anorthosite which lies near, and closely resembles Marcy anorthosite. Both dikes just mentioned are quite certainly off-shoots from large bodies of typical granite which, in a general way, cut into the marginal portion of the great body of anorthosite. A wide dike of gray granite cuts Marcy anorthosite just north of the summit of Texas ridge (see map). The granite is very gneissoid with highly flattened quartz and feldspar crystals. The small mass of Whiteface anorthosite on the side of Beech hill (see map) is cut by a number of narrow dikes of granitic syenite and granite which are doubtless off-shoots from the large surrounding body of syenite-granite. Contacts between these dikes and the anorthosite are usually not very sharp.

Also in the Schroon Lake quadrangle many dikes or narrow intrusive bodies of syenite and granite were observed in the areas of anorthosite and syenite-granite mixed rocks, and to some extent in the areas of Keene gneiss. Some of these are referred to below. The evidence, therefore, from the dikes, that the syenite-granite series is distinctly younger than the anorthosite series, is very strong.

Broad intrusive tongues of syenite and granite in anorthosite. Broad tongues of syenite and granite extending, in a number of places for miles, into the great body of anorthosite furnish perhaps even more impressive evidence than the dikes that the syenite-granite series is really younger than the anorthosite.

Cushing's Long Lake geologic map shows an intrusive tongue of syenite from 1 to 3 miles wide cutting into the anorthosite for a distance of 2 miles.

The writer's Lake Placid geologic map shows a fine example of a tongue of syenite-granite with a maximum width of 1½ miles cutting Whiteface anorthosite across a portion of Wilmington mountain. A great body of syenite-granite from 1 to 6 miles wide extends into the anorthosite for 13 miles across the Lake Placid quadrangle, and thence for an unknown distance into the Mount Marcy quadrangle on the south.

In the Schroon Lake quadrangle, a tongue of granite from 2 to 4 miles wide in the vicinity of Cheney pond extends into the anorthosite for fully 4 miles, reaching all the way through the border facies and into the Marcy anorthosite (see map). The large intrusive mass of later gabbro lies within this salient and cuts out much of the originally present granite. Two of the small dikes of granite above mentioned are off-shoots of this salient of granite in the anorthosite.

Inclusions of anorthosite in the syenite-granite. Inclusions of anorthosite in the syenite-granite series furnish very strong evidence that the syenite-granite body is an intrusive distinctly separate from, and later than, the anorthosite. Such evidence is scarcely, if at all, mentioned by Bowen, probably because few examples of such inclusions were known to him. Many excellent examples have come under the writer's observation.

It seems evident from a glance at the accompanying Schroon Lake geologic map that the anorthosite once extended out as a continuous broad belt at least 7 or 8 miles beyond the present margin of the Marcy anorthosite because, within that distance from the Marcy anorthosite, there are many inclusions of anorthosite (mostly of sufficient size to be mapped) in the syenite-granite series all the way across the quadrangle. In other words, only mere remnants of the former anorthosite are now visible. With the exception of one locality, these are all inclusions of Whiteface anorthosite. The exceptional locality is of particular interest. It is on top of Wilson mountain, and represented on the geologic map as a small area of mixed rocks. One patch of the granite 12 feet across contains large dark bluish gray labradorites an inch or more across and several small pieces of typical Marcy anorthosite as distinct inclusions, mostly arranged roughly parallel to the foliation of the granite (see figure 1). Immediately around the larger fragments the granite exhibits fine magmatic flow-structure. A similar exposure occurs close by. A reasonable interpretation is that the granite magma moving upward enveloped two small masses of Marcy anorthosite and tore them into small fragments which became somewhat scattered and arranged parallel to distinct magmatic currents which moved up nearly vertically as shown by the high angle of dip of the magmatic flow-structure foliation.

A fine example is in the bed of the brook 1 mile southeast of the summit of Oliver hill where a mass of Whiteface anorthosite 20 feet across is inclosed in the granite (see map). This outcrop con-

sists of alternating bands of partly white and partly rather gabbroid Whiteface anorthosite.

An interesting ledge outcrops in the small mapped area 1½ miles a little west of north of Irishtown. The rock is extremely gneissoid, moderately gabbroid, Whiteface anorthosite containing many lens-shaped labradorities or "augen" up to 1½ inches long, and in some portions red garnets. This anorthosite also has in it many

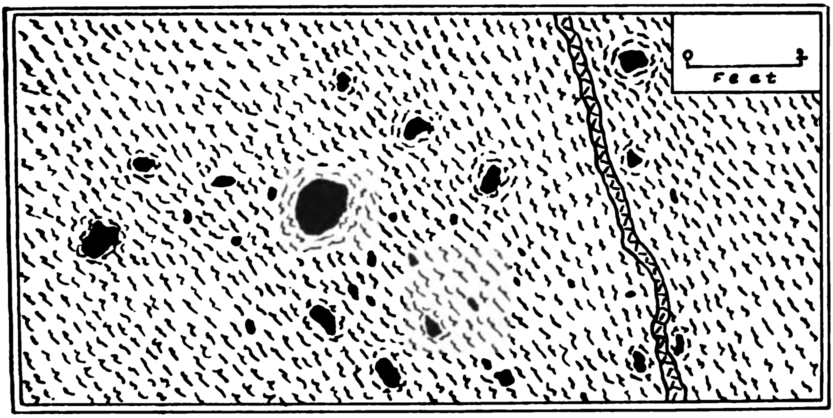


Fig. 1. Sketch of part of an exposure on top of Wilson mountain showing small inclusions of Marcy anorthosite in gneissoid granite. Note the magmatic flow-structure foliation about the larger fragments.

inclusions of Grenville hornblende-garnet gneiss in the form of lenses, strips and layers from less than 1 foot long to 1 or 2 rods long, these being arranged parallel to the foliation of the ledge. It is thus certain that this anorthosite must have been in a truly magmatic state when it caught up the fragments of Grenville. The immediate relation of this ledge to the nearby syenite is obscured by drift, but no doubt it is an inclusion.

Along the western side of the Beech hill anorthosite, which is an inclusion in the syenite-granite, there are, in the granite, some small, irregular inclusions of Whiteface anorthosite with indefinite boundaries, and with distinctly curving flow-structure in the granite around them.

In the narrow belt one-fourth of a mile long, already described as extending across the southern brow of Cobble hill, many small inclusions of the Whiteface rock occur in the granite.

A number of inclusions of the Whiteface rock, each from 1 to 20 feet across, are finely shown in the granitic syenite on top of the hill 1 mile east-southeast of Cobble hill.

All the inclusions of anorthosite above mentioned bear exactly the same relations to the inclosing syenite-granite as do the inclusions of Grenville, and it seems clear that the upward moving syenite-granite magma enveloped masses of both these rock series in exactly the same manner. Thus we have just as strong evidence that the syenite-granite is distinctly younger than the anorthosite as that it is distinctly younger than the Grenville.

Absence of Grenville and syenite-granite from the anorthosite area. It is a striking fact that both Grenville and syenite-granite are almost, if not quite, absent from a large part of the anorthosite area of the Adirondacks. In the northeastern half of the anorthosite area there are considerable developments of both Grenville and syenite-granite. In the southwestern half of the Adirondack anorthosite area, including the Schroon Lake quadrangle, the absence of Grenville and syenite or granite is, however, an impressive fact, though it must be remembered that many square miles of this have not been carefully studied. The detailed Long Lake, Schroon Lake and Paradox Lake maps, and the southern half of the Elizabethtown map, show no Grenville or syenite-granite well within the anorthosite there mapped. So far as known to the writer this is also true of the southern half of the Mount Marcy quadrangle.

Bowen, in his paper on "The Problem of the Anorthosites," dwells upon this absence of Grenville and syenite-granite from so much of the anorthosite, and he offers an explanation briefly stated as follows:[1] "If one pictures the syenite and the anorthosite as conventional batholiths, some difficulty is experienced in accounting for the foregoing facts [see above paragraph]. It is necessary to imagine an early intrusion of a huge plug of anorthosite followed by an intrustion of syenite which took the form of a hollow cylinder circumscribing it and invading it only peripherally. . . . On the other hand, if one pictures the Adirondack complex as essentially a sheetlike mass with syenite overlying anorthosite . . . one would expect to find areas of Grenville roof covering the syenite in places and to find it relatively little disturbed. In the interior and eastern region of maximum uplift one would expect to find the deep-seated anorthosite laid bare and to find it free from areas of the roof." Also, he says, because of the deep erosion in the region of maximum uplift one would expect to find the layer of syenite removed.

[1] Jour. Geol., 25:223-24. 1917.

Some of the more important objections to the view just expressed are: (1) the anorthosite represents a separate and distinctly older intrusion than the syenite-granite, and so the sheetlike arrangement advocated by Bowen is out of the question; (2) the Adirondack anorthosite area is by no means practically free from masses of syenite-granite, this being particularly true of the whole northeastern half of the area where there are many large and small bodies of syenite and granite in the form of real intrusives in the anorthosite; and (3) it is not at all necessary to assume that both syenite-granite and anorthosite were batholithic intrusions.

An explanation offered by the writer to account for the absence of Grenville and syenite-granite from so much of the anorthosite area may be briefly stated as follows. The anorthosite is considered to be a laccolith not much greater across than the present area of outcrop. Its intrusion was soon followed by a very irregular intrusion of the great body of generally rather highly fluid syenite-granite magma. That the syenite-granite magma was mostly rather highly fluid is proved by its great power to cross-cut, intimately penetrate, break up and tilt the Grenville strata. Only exceptionally did local portions of this magma invade the Grenville strata in true laccolithic fashion. Both the anorthosite and the syenite-granite are believed to have intruded a very thick mass of essentially undisturbed Grenville strata, largely or altogether free from orthogneiss. The southwestern half of the anorthosite body, which is so free from masses of Grenville and syenite-granite, is believed to represent the greatest bulk of the anorthosite where the laccolithic magma was thickest and reached its highest level. The northeastern half of the anorthosite as now exposed is regarded as the portion where the anorthosite magma spread out as a relatively much thinner layer whose surface was at a notably lower level than that of the thicker portion to the southwest (see figure 2). Because of the greater uplift of the southwestern portion, the Grenville cover has there been almost, if not completely, removed by erosion. But many areas of the Grenville roof remain over the thinner northeastern part of the anorthosite where the uplift was much less. Thus we have a simple explanation of the absence of the Grenville from so much of the anorthosite area. After the solidification of the great body of anorthosite, the syenite-granite magma was batholithically intruded in a rather highly fluid state, and it tended to avoid penetration of the anorthosite which was much more massive, homogeneous and

resistant than the great mass of surrounding practically undisturbed Grenville strata. This satisfactorily explains not only why syenite-granite masses are scarcer within the anorthosite area than in the Adirondack region in general, but also why syenite-granite is almost, or entirely, absent from the southwestern half of the anorthosite area. May not there have been a wide magmatic feeding channel extending northwest by southeast under the main body of the southwestern half of the anorthosite? On this view, the thickest portion of the laccolith developed directly over the wide feeding channel which extended far down, with the result that this portion of the anorthosite intrusive body was very resistant to intrusion by the syenite-granite magma. The northeastern portion of the anorthosite, because notably thinner, was penetrated by considerable masses of the syenite-granite magma, as, for example, in the Lake Placid and Ausable quadrangles. Here again we have a simple explanation of the field facts.

Strongly supporting the above conception is the evidence from the distribution of the stocks of later gabbro. All the recent workers in Adirondack geology recognize this gabbro as distinctly younger than the syenite-granite series. It usually occurs in the form of stocks or pipelike bodies rarely more than a few miles across. Such stocks are common and widespread throughout the Adirondack region, except the anorthosite area. Like the syenite-granite, this gabbro is singularly absent from the southwestern half of the anorthosite area. In the Schroon Lake and Elizabethtown quadrangles a number of such gabbro stocks each from 2 to 4 miles long lie right along the border of the anorthosite but none well within it. In the northeastern half of the anorthosite area gabbro stocks occur in moderate size and number. It is, then, very clear that this later gabbro shows the same sort of distribution with reference to the anorthosite as does the syenite-granite, and it is believed that the same explanation (see above) applies to both. Evidently the gabbro intrusions, too, were unable to penetrate the thick, very resistant southwestern half of the anorthosite laccolith.

Origin of the anorthosite by differentiation in a laccolith of gabbroid magma. *Laccolithic structure of the anorthosite.* After considering a number of the better known anorthosite bodies of the world, Daly[1] concludes that all of them, including the Adirondack mass, are to be regarded as laccoliths.

[2] Igneous Rocks and Their Origin, p. 328–35. 1914.

The writer believes the Adirondack anorthosite (not necessarily the anorthosite as such) was intruded essentially laccolithically, and the syenite-granite was intruded essentially batholithically. But it is not at all necessary to assume, as does Bowen, that both great bodies are batholithic if they are regarded as distinctly separate intrusions.

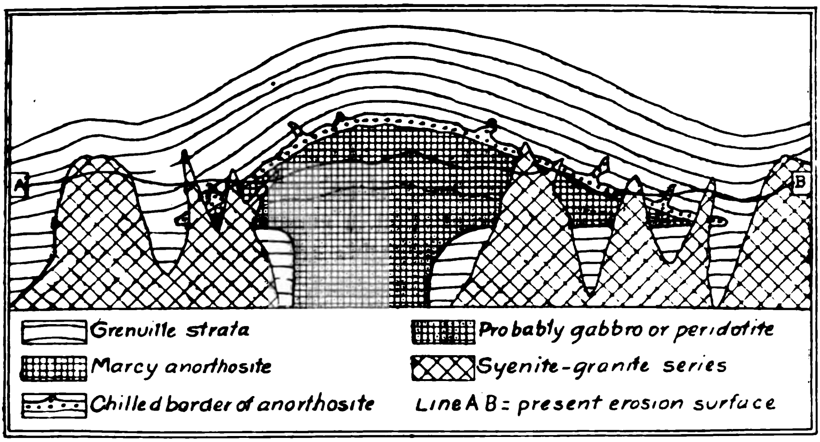


Fig. 2 Highly generalized northwest-southwest structure section through the Adirondack anorthosite body, showing the relation of the anorthosite to the Grenville and syenite-granite series

Positive proof for the laccolithic structure of the Adirondack anorthosite can not be won from a study of its relation to the intruded Grenville strata. In the first place, only a very few (usually small) areas of Grenville are known to lie against the borders of the anorthosite because the Grenville has been so extensively cut out by the syenite-granite, and these few contacts are almost all concealed under Pleistocene deposits. In the second place, such Grenville strata were more or less disturbed a second time by the later syenite-granite intrusion.

Many of the most important field facts best harmonize with the conception of a laccolithic structure of the Adirondack anorthosite. Among these facts which have already been discussed, are the following: The chilled border facies which developed as an upper as well as an outer margin resting directly upon and against the Marcy anorthosite; failure to find masses of Grenville farther down in the body of the anorthosite than just below the level of the inner margin of the chilled border, thus indicating the power of the

anorthosite to have lifted rather than to have extensively cross-cut or engulfed Grenville strata; and failure of both syenite-granite and later gabbro to penetrate the southwestern half of the great anorthosite body, and moderate penetration of the northeastern half by the rocks just named, thus very strongly suggesting a laccolith very thick toward the southwest and relatively thin toward the northeast.

Probable origin of the anorthosite by settling of femic minerals. The writer's conception is that the anorthosite resulted from the settling of femic constituents in an originally gabbroid intruded or intruding magma. This is fundamentally the view expressed by Daly[1] who says: "The anorthosites of the world are best regarded as . . . gravitative differentiates of gabbroid magma" usually in laccoliths. Regarding differentiation in general by sinking of crystals, F. W. Clarke[2] says: "Gravitative adjustment is presumably most effective in slowly cooling magmas, especially when partial crystallization has occurred. The minerals first formed must have time to sink. The rate of cooling, therefore, is a distinct factor in the differentiation of igneous rocks." There is every reason to think that the great igneous body of Adirondack anorthosite cooled very slowly.

Very briefly stated, the writer considers the main steps in the development of the anorthosite to have been as follows: first, intrusion of a laccolithic body of gabbroid magma only somewhat greater across than the exposed area of the anorthosite; second, relatively rapid cooling of the marginal portion to give rise to the chilled gabbroid border phase; and, third, settling of many of the slowly crystallizing femic minerals in the still molten interior portion of the laccolith, leaving a great body of magma to crystallize gradually into anorthosite. Thus at the bottom, and probably nowhere visible in the field, lies a mass of pyroxenite or peridotite; next above it the thick body of Marcy anorthosite; and at the top and on the outer margins the chilled gabbroid border facies known as Whiteface anorthosite.

The border facies thus merely represents the very outer and upper portions of the original gabbroid magma which solidified too rapidly to permit much settling or separation of femic minerals from it. This marginal phase came into direct contact with the

[1] Igneous Rocks and Their Origin, p. 229–43. 1914.
[2] U. S. Geol. Survey Bul. 491, p. 297. 1911.

country rock (Grenville) and, at first, when it was in its most highly fluid state, attacked the country rock with sufficient force to engulf portions of it, send some dikes into it, and even intimately penetrate it. Such phenomena have been observed in the Lake Placid and the Schroon Lake quadrangles. For most part, however, the gabbroid magma was too stiff to cross-cut, penetrate, break up and tilt masses of the Grenville in a manner at all comparable to the later syenite-granite magma.

Soon after the intrusion of the laccolith, many of the femic minerals which began to form in the magma just below and within the chilled border phase began to precipitate, thus permitting the accumulation of plagioclase in the upper levels of the magmatic chamber. Though this idea of settling of femic minerals is much like that advocated by Bowen, the writer's hypothesis differs in two important respects. First, the anorthosite did not form by settling of plagioclase crystals, and, second, there was no development of syenite-granite residual magma over the anorthosite. It is not necessary to believe that there was any great amount of settling of femic constituents unless we assume a very femic original gabbroid magma, because femic minerals up to fully 10 per cent never precipitated at all, these being now present in the typical Marcy anorthosite. Further, the femic constituents did not settle through anything like such a thick mass of magma as required by Bowen's hypothesis, and only heavy femic minerals sank, and not femic minerals followed by plagioclase in a magma which must have become increasingly viscous.

It is evident, then, that the gabbroid magma in the Adirondack region must, to the very last of the process, have contained at least a very considerable percentage of liquid of sufficient fluidity to have allowed the crystals to sink through, and this residual magma is represented by the present anorthosite, which was once to a very considerable degree molten as such. Could the magma have possessed sufficient fluidity long enough to have permitted repeated wholesale sinking of crystals through a very great thickness of magma as required by Bowen's hypothesis?

Origin of variations in the anorthosite. As already shown, the anorthosite contains many zones or belts and irregular-shaped portions, some distinctly more gabbroid, and others distinctly more highly feldspathic than the average Marcy anorthosite. Many of these show relatively wide gradation zones into the typical rock,

while others are more sharply separated. There are also many degrees of foliation and granulation, and differences in coarseness of grain.

The conception of the origin of such variations which best harmonizes with the field facts may be briefly stated as follows. During the crystallization of the anorthosite magma, formed by the process outlined above, there was local differentiation in the upper portion of the magma reservoir whereby many portions relatively richer in femic constituents separated from the much larger portions relatively poor in femic constituents. The more femic portions, which contained more liquid, and hence were freer to flow, were, in many cases, more or less shifted by movements during a late stage of magma consolidation to form the crude bands or zones often well foliated and rather sharply separated from the purer anorthosite. Those belts or zones of more gabbroid anorthosite which gradually pass into purer anorthosite probably represent differentiates essentially *in situ*. That there must have been notable movements during a late stage of magma consolidation is abundantly proved by the magmatic flow-structure foliation, more especially in the gabbroid zones, but also not rarely in the typical Marcy anorthosite. It is also believed that these late magmatic movements caused much, or all, of the notable granulation of the anorthosite. But this granulation is by no means true only of the anorthosite. The syenite-granite series and the later gabbro usually exhibit high degrees of granulation and more or less well-developed foliation due to the same cause.

Syenite-granite Series

General statements. The syenite-granite series is very prominently developed in the Schroon Lake quadrangle where it occupies most of the southeastern half of the area. Definitely known areas, essentially free from intimate associations with other rocks, total fully 75 square miles. To these must be added a few square miles more which are mapped with the mixed rocks or are concealed in the areas mapped as Pleistocene. The syenite-granite series is, therefore, about as extensively developed as the anorthosite series of the quadrangle. No syenite or granite whatever was found in the great area of Marcy anorthosite, and an explanation of this fact is offered above in the discussion of the anorthosite. The

series shows many variations from quartz syenite through granitic syenite to granite. Since it is part of, and in almost every way similar to, the well-known syenite-granite series of the Adirondack region, it seems unnecessary to enter into detailed descriptions here. The interested reader will find more or less elaborate descriptions and discussions of the age and relations of the syenite-granite series in the various special papers and New York State Museum bulletins pertaining to the Adirondack region.

That the syenite-granite is younger than the anorthosite of the quadrangle is proved by dikes and a broad tongue of granite intrusive into the anorthosite, and by inclusions of anorthosite in both the syenite and granite. Actual examples are cited above in the discussion of the anorthosite. In fact, the occurrence of numerous small to large inclusions and isolated areas of anorthosite in the syenite-granite series as far out as 7 or 8 miles from the solid body of anorthosite, strongly supports the view that the whole anorthosite border was badly intruded and cut to pieces by the syenite-granite magma, the present inclusions and isolated masses being merely remnants of the former more extensive body of anorthosite.

That the syenite-granite is distinctly younger than the Grenville is abundantly proved by many small to large inclusions of the Grenville, and by tongues and dikes of the syenite or granite in the Grenville. Some of the inclusions large enough to be separately mapped are, 1 mile northwest of Schroon Lake village; western side of Thurman pond; one-half of a mile east of South Schroon; western face of Wilson mountain; both south and west of Oliver pond; 1½ miles east of Sherman pond; 1¼ miles west-southwest, and 1½ miles north-northwest of the summit of Hayes mountain; and 1½ miles east-southeast of Boreas river. Most of these are lens-shaped inclusions parallel to the foliation of the inclosing rocks. The larger masses of Grenville represented on the geologic map are probably also best to be regarded as inclusions. In the granite of the Lester dam mixed rock area there are numerous drawn out or lenslike inclusions of hornblende gneiss. The mixed rocks in the areas south of Calahan pond, southwest of Minerva, west and southwest of Charley hill, north of Loch Muller, and west of Schroon Lake village are Grenville gneisses all cut to pieces by dikes or tongues of syenite or granite. Tongues or broad

dikes of granite and syenite extending right out into Grenville are well represented on the map north and northwest of Minerva, and south-southwest of Irishtown.

Description of syenite and granitic syenite. Practically all the syenite of the quadrangle is more or less quartzose. As has been the writer's custom for some years, when the rock contains not over 20 per cent quartz it is classed as normal quartz syenite, when the quartz content lies between 20 and 25 per cent it is called granitic syenite, and when there is more than 25 per cent quartz the rock is called granite. The syenite of the quadrangle is much less extensively developed than usual in the Adirondack region, and much of this is really granitic syenite, no attempt having been made to separate the normal and granitic phases on the geologic map because of the general unsatisfactoriness of exposures.

The two facies of the syenite are typically medium grained, though somewhat variable to finer and coarser grained. Distinctly porphyritic facies were not observed. Granulation is very common, in some cases being highly developed especially as regards the feldspar, and less commonly the quartz.

A dark greenish gray is the prevailing color of the fresh syenite as usual in the Adirondacks, though the more granitic facies are often pinkish gray. Reddish syenite, directly associated with green syenite, is well exposed in and near the quarries one-half of a mile east of South Schroon. All, except some of the pinkish facies relatively free from femic minerals, weather to light brown, the weathered portion seldom extending more than a few inches below the surface.

Seldom does the syenite fail to exhibit a foliated structure. It is, in most cases, moderately developed, but in some cases it is faint and in others very pronounced.

It should be noted that marked differences in granularity, granulation, foliation and color not uncommonly occur locally, in some cases in single outcrops, or even in hand specimens.

Very typical, fresh, moderately gneissoid, greenish gray, normal quartz syenite is finely exposed in the larger of the two quarries by the road one-half of a mile east of South Schroon. No. 6 of table 2 shows the mineral content of a thin section of this rock.

Table 2 Thin sections of syenite, granitic syenite, and granite

	Slide no.	Field no.	Microperthite	Orthoclase	Oligoclase	Microcline	Andesine	Quartz	Hornblende	Pyrox. (Mono.)	Diallage	Hypersthene	Chlorite	Hematite	Magnetite	Pyrite	Biotite	Garnet	Apatite	Zircon	Sericite	Calcite
Syenite and granitic syenite	5	4 l 5	45	8	10	..	..	22	5	..	..	..	4	3	2	.....	.....	..	½	½	....	..
	6	4 l 2	66	4	7	..	..	15	2	..	3	2	..	..	¾	.....	.....	..	little	little	....	..
	7	6 g 6	35	20	30	..	..	8	....	..	5	..	..	..	1	¼	little	..	½	¼	....	..
	26	9 f 2	40	13	10	..	..	20	2	7	..	2	..	..	2	.....	.....	3½	¼	¼	....	..
	28	10 g 10	80	..	5	..	..	13	½	..	1	..	..	..	½	.....	.....	..	little	little	....	..
	49	8 m 5	64	..	6	..	4	15	2	3	..	..	..	..	2½	.....	.....	2½	½	½	....	..
Granite	1	1 k 8	20	..	1	40	..	34	3	..	..	..	..	..	¼	.....	1	..	little	½	little	..
	2	2 c 4	50	..	3	..	..	40	5	..	..	..	..	..	¼	.....	1	..	¼	½	....	..
	3	2 m 2	24	..	2	24	..	42	6	..	..	..	..	¼	¼	.....	½	..	¾	¼	....	..
	4	3 h 1	46	5	2	2	..	40	2½	..	..	..	..	..	½	1½	.....	..	¼	¼	....	..
	8	8 f 3	41	..	8	..	..	35	15	..	..	..	..	..	..	.....	½	..	¼	¼	....	..
	9	13 f 6	52	6	..	..	..	30	....	..	..	..	..	..	¼	.....	1½	..	little	little	....	..
	25	9 d 3	35	15	1	..	..	40	....	..	..	..	1	..	½	.....	.....	7	¼	¼	....	..
	31	10 g 2	57	..	1	..	..	35	5	..	..	..	..	..	½	.....	.....	1½	little	.....	....	..
	32	9 b 1	33	..	6	..	4	35	12	4	..	..	..	..	1½	little	¼	3½	¼	little	....	½
	34	8 f 13 b	65	..	..	..	5	28	li:tle	..	1	..	½	..	½	.....	.....	..	little	.....	....	..
	35	8 f 25b	54	..	2	..	..	35	2	..	4	..	..	..	2	.....	.....	½	½	little	....	..

No. 5, by road one-third of a mile east of South Schroon; no. 6, quarry one-half of a mile east-northeast of South Schroon; no. 7, cross-roads one-half of a mile northeast of Muller pond; no. 26, one-half of a mile north-northwest of Bailey pond; no. 28, from granitic syenite area 1¾ miles northeast of Bailey pond; no. 49, southeastern base of Severance hill; no. 1, top of hill 1½ miles southwest of Taylors on Schroon; no. 2, quarry one-half of a mile a little west of north of Moxham pond; no. 3, lake shore one-third of a mile northwest of Adirondack village; no. 4, 1 mile east-northeast of Pat pond; no. 8, one-half of a mile northeast of summit of Cobble hill; no. 9, from tongue of granite cutting anorthosite 1 mile south of Sand pond; no. 25, old road crossing Minerva stream 1 mile north of mouth of Hewitt pond brook; no. 31, east of brook at north end of granite area 2 miles northeast of Bailey pond; no. 32, little hill just west of Hewitt pond; nos. 34 and 35, southern brow of Cobble hill.

From table 2 it is seen that microperthite always occurs as the most prominent constituent of the syenite, while oligoclase and quartz are always present in smaller amounts. Orthoclase is more variable and sometimes absent. No. 7 is a fine example of a distinctly basic or dioritic facies of the syenite. Nos. 26 and 49 show reaction rims of garnet around magnetite. No. 31 is highly granulated along some zones parallel to the foliation in the thin section.

Description of granite and granite porphyry. The granite and granite porphyry are regarded as differentiation facies of the great Adirondack syenite-granite series. There are many places where

the syenite grades through granitic syenite into granite, but not a single locality was observed where syenite definitely cuts granite or vice versa. The writer has been unable to demonstrate the existence of any considerable mass of granite either distinctly older or younger than the normal syenite, though small pegmatite and aplite dikes are not uncommon.

As regards granularity, granulation and foliation the statements above made with reference to the syenite apply almost equally well here. Excessively gneissoid granite with highly flattened quartz and feldspar were observed, among other places, one-fourth of a mile northeast of the summit of Cobble hill, on the southern brow of Bigsby hill, at the summit of Oliver hill, and in the small area of granite just east of the brook near the trail 2 miles northeast of Bailey pond.

Most of the granite is pinkish gray, to pink, or even reddish where fresh, but locally it is greenish gray or gray. It usually weathers to pinkish gray or light brown.

Like the syenite, the granite exhibits many local variations. A hand specimen from a ledge by the lake shore one-fifth of a mile north of the Adirondack village steamer landing is distinctly foliated and granulated, with one pink band especially rich in feldspar adjacent to a band very rich in quartz plus some garnets, these two bands having on either side granite consisting of quartz, feldspar, and hornblende with some biotite. These bands are not sharply separated. In the quarry one-half of a mile north of Moxham pond, the granite shows notable variations in coarseness of grain often within a foot or two.

Table 2 shows the minerals contained in some thin sections of the granite. From this table it is seen that the two most conspicuous never failing constituents are microperthite and quartz. In a few slides microcline occurs, and in only two does it equal or exceed the microperthite. Orthoclase usually fails and it is never prominent.

Granite with scattering garnets was observed in several places as, for example, the whole mass of Pine hill, three-fourths of a mile west-southwest of Taylors on Schroon, on top of Ledge hill, and by the road three-fourths of a mile north-northeast of Pat pond.

In a number of localities numerous lenslike inclusions of hornblende gneiss (metagabbro or Grenville), too small to be mapped, occur in the granite as, for example, one-half of a mile west of Oliver pond, at the summit of Cobble hill, and on Ledge hill just

north of the small gabbro stock. An inclusion of particular interest is shown in figure 8.

The granite porphyry is quite certainly a differentiation phase of the granite, and it is only moderately developed within the quadrangle. One small area is represented on the map in the very southeastern corner, and another on the southern brow of Ledge hill, while the largest area (about 1 square mile) takes in the vicinity of Pat pond. The granite porphyry differs from the granite only in being coarser grained and usually more or less porphyritic.

Grenville or Hornblende Gneiss (Metagabbro?) and Syenite-granite Mixed Rocks

A number of small areas of mixed rocks of this sort are represented on the geologic map. The Grenville or hornblende gneiss (metagabbro?) and granite are so intimately associated that any attempt to separate them on the map would be unsatisfactory. The old rocks are usually cut to pieces by, or form inclusions in, the syenite-granite.

In the small area just south of Calahan pond, typical granite contains small to large well-defined inclusions of Grenville. In the two garnet mines, the larger of which is located near the edge of the map and the other just to the west, the rocks are highly granular red garnet in considerable masses closely associated with coarse pyroxenic crystalline limestone. Contacts are sharp against the granite in the smaller mine, but not in the larger one. A few rods to the north and by the old road, there is a small, sharply defined inclusion of limestone in the granite parallel to the foliation of the latter.

In the area covering about one-half of a square mile southwest of Minerva there are many outcrops of both granite and Grenville, the two often being closely associated in single outcrops. Evidently the Grenville has here been badly cut to pieces by the granite.

The mixed rocks of the small area 2 miles north of Minerva are described along with the associated iron ores in the last chapter of this bulletin.

At and near Lester dam there are extensive outcrops of pinkish, very gneissoid granite containing much hornblende gneiss in the form of flattened or lenslike inclusions more or less fused into the mass.

The small area three-fourths of a mile north of Loch Muller shows good exposures of hornblende and hornblende-garnet gneisses shot through by some dikes of granite. Some of the garnets up to 1 or 2 inches in diameter have distinct rims of hornblende.

In the small area three-fourths of a mile northwest of Loch Muller, hornblende gneiss (metagabbro?) is shot through by granite and considerable magnetite is associated with the rocks.

Of the small areas west and southwest of Charley hill, the two farthest out are chiefly granite with considerable intermixed older dark gneisses, while the one nearer Charley hill is chiefly well-bedded hornblende gneiss shot through by irregular dikes of granitic syenite.

The small area 1 mile south-southwest of South Schroon is mostly hornblende gneiss intricately cut into, and apparently more or less assimilated by, granite.

The area of about one-fourth of a square mile 1 mile west of Schroon Lake village shows many good exposures of hornblende and hornblende-garnet gneisses, some very intimately associated with granite in the form of small streaks and bands, and some less intimately associated in bodies of considerable size.

An exposure by the road 1½ miles a little north of west of Schroon Lake village consists of very gneissoid to almost banded intimately mixed dark gneiss and granite.

The small area 1 mile northeast of South Schroon contains very gneissoid syenite or granitic syenite more or less intimately associated with Grenville hornblende and pyroxene gneisses.

Hornblende gneiss and syenite are associated in the area on the west side of Thurman pond.

Keene Gneiss

General statements. One of the most interesting rock types of the region is locally developed as belts or irregular bodies along or near portions of the borders between the anorthosite and the syenite-granite series. Both the Marcy and Whiteface types of anorthosite show such border rocks. There is very strong evidence, based upon field work and a study of thin sections, that this is really a transition rock between anorthosite and syenite or granite formed by actual digestion or assimilation of anorthosite by the invading syenite-granite magma along portions of its borders. The writer has proposed that this rock be called "Keene gneiss," because a fine exposure of the typical fresh rock occurs by the

road just north of the village of Keene in the Lake Placid quadrangle.

Fifteen areas of mostly Keene gneiss are represented on the writer's Lake Placid geologic map and the rocks are described in the accompanying report. Cushing has described rocks which probably belong in the same category, from two localities on the western side of the great anorthosite area. Cushing suggests that these rocks, particularly in the Long Lake quadrangle, are magmatic assimilation products. Kemp has described certain peculiar types of gabbro, called the Woolen Mill and Split Rock Falls types, as occurring in the Elizabethtown quadrangle. Kemp says nothing regarding the origin of these types, but, in the writer's judgment, they are to be classed as Keene gneiss. These seem to be the only rocks of the sort in the Adirondack region regarding which even brief published statements by other workers have been made. The whole problem of the Keene gneiss is rather fully discussed in the writer's recent paper[1] on "Adirondack Anorthosite."

Megascopic characters. The typical Keene gneiss presents a different appearance from any other Adirondack rock. In the Lake Placid and Schroon Lake quadrangles, the typical rock is medium grained, gneissoid, notably granulated, and looks much like some facies of the syenite-granite series except for scattering phenocrysts of bluish gray labradorites up to an inch long. These phenocrysts, which are rounded and usually elongated parallel to the foliation of the rock, doubtless represent cores of crystals which survived the process of granulation. Locally the phenocrysts are absent or only sparingly present, and such facies of the Keene gneiss are often difficult to distinguish in the field from certain phases of the syenite-granite series. Under the microscope, however, the distinction may generally be made. A gneissoid structure is nearly always present but it varies notably, in some cases being practically absent. The fresh rock is usually greenish gray, and it weathers brown.

Microscopic characters. The mineral contents of thin sections of selected samples of various phases of the rock from the Schroon Lake quadrangle are shown in table 3. It is quite clear from this table that the Keene gneiss is mostly distinctly intermediate in composition between the syenite-granite and the anorthosite.

[1] Geol. Soc. Amer. Bul. v. 29, no. 4. 1918.

Table 3 Thin sections of Keene gneiss

Slide no.	Field no.	Orthoclase	Olig.-And.	Olig.-Lab.	Quartz	Pyrox. (Mono.)	Hornblende	Chlorite	Garnet	Magnetite	Pyrite	Apatite	Zircon	Zoisite	Titanite	Biotite
27	9 f 2	21	66	....	....	7	2	....	2	1	......	......	......	1	little	...
29	10 g 12	....	....	92	7	....	½	....	......	½	......	little	......	...	......	...
30	10 f 2	45	25	....	15	5	4	....	4	1	......	1	......	...	......	...
33	12 f 4	....	....	75	7	4	2	....	8	2	......	little	......	2	......	...
36	8 f 13 a	30	....	56	10	....	3	....	little	½	little	½	......	...	......	...
36a	8 f 13 a	15	....	36	10	30	5	....	3	½	little	½	......	...	......	...
38	8 f 25 a	10	75	....	15	4	3	....	2	1	......	......	......	...	......	...
46	8 c 5	20	38	....	....	....	35	....	......	6	½	½	little	...	......	½
48	8 d 9	12	....	35	1	25	20	....	little	6	½	½	little	...	......	..

No. 27, one-half of a mile north-northwest of Bailey pond; no. 29, just north of the granite by the trail 2 miles northeast of Bailey pond; no. 30, 1 mile northeast of Bailey pond; no. 33, eastern slope of Bailey hill; nos. 36, 36a and 38, southern brow of Cobble hill; no. 46, just south of the brook 1 mile east of Hewitt pond; no. 48, one-fourth of a mile south of the mouth of Hewitt pond brook.

Descriptions of occurrences in the Schroon Lake quadrangle. Most of the Keene gneiss of the quadrangle occurs in the two largest areas separately mapped as such, but in the areas mapped as anorthosite and syenite-granite mixed rocks, there are many excellent local developments, and certain of these will be considered first.

An outcrop on the southern brow of Cobble hill, 1 mile due south of Bailey pond, is very significant because of the light it throws upon the local origin of the Keene gneiss. The accompanying sketch (figure 3) shows the relationships. This Keene gneiss is distinctly granitic or syenitic in appearance except for the many labradorite crystals, mostly an inch long, which stand out as phenocrysts more or less parallel to the crude foliation of the otherwise medium grained rock. Nos. 36, 36a and 38 represent thin sections of this Keene gneiss which, though variable, is distinctly intermediate between the granite and the anorthosite in the same ledge. Within this Keene gneiss there are inclusions of Whiteface anorthosite (no. 37 of table 1) which contain some large labradorites and also scattering femic minerals up to 2 inches long, more or less lenslike and parallel to a distinct foliation. Contacts between the inclusions and the Keene gneiss are not very

sharp. Immediately above this Keene gneiss, but not in very sharp contact with it, is a very gneissoid granite (nos. 34 and 35 of table 2) which contains many garnets. This gneissoid granite grades upward into typical, medium grained, only moderately foliated granite without garnets. A similar typical granite lies against the Keene gneiss at the bottom, but the contact there is quite sharp. The writer's interpretation is that the upward moving granite magma more or less assimilated some Marcy or Whiteface

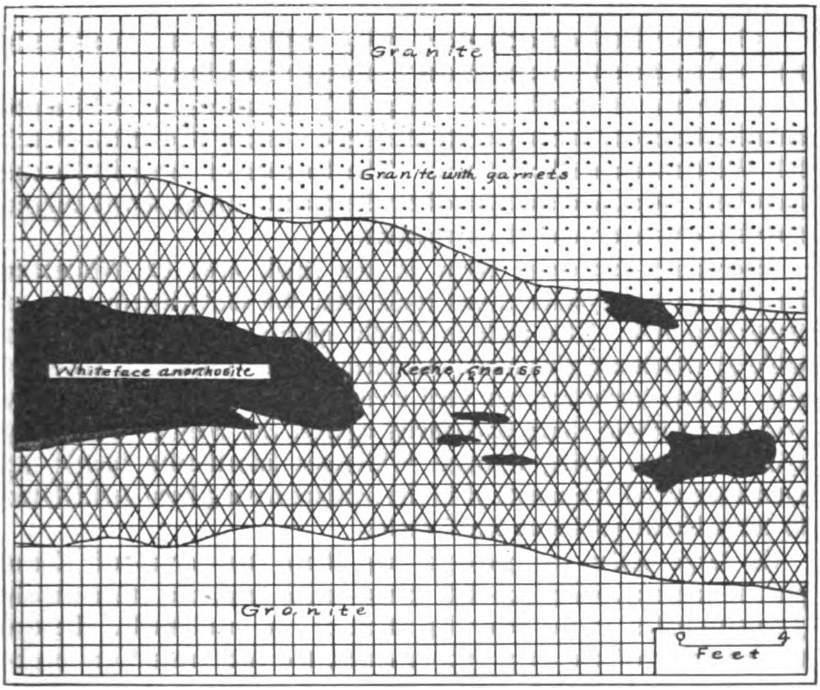


Fig. 3 Sketch of part of the great ledge at the southern brow of Cobble hill showing Keene gneiss in its relation to both granite and Whiteface anorthosite. Contacts between the Keene gneiss and both Whiteface anorthosite and garnetiferous granite are not sharp, but the contact between the Keene gneiss and the lower granite is rather sharp.

anorthosite at a considerable depth, and that this molten mass (Keene gneiss magma) rose still higher and caught up and only partly fused the borders of fragments of Whiteface anorthosite. The origin of the garnetiferous granite is not so certain, though it may represent a mass of granite with a small quantity of anorthosite very thoroughly digested.

An interesting assemblage of rocks is well exposed on the steep hillside one-half of a mile north-northwest of Bailey pond. Commonest of all is good Whiteface anorthosite, but some tongues or dikes of granite cut through it, and still other rock is quite certainly an assimilation product of the two, that is to say, Keene gneiss. Most of the rock taken to be Keene gneiss is of syenitic aspect both with and without quartz, but some contains phenocrysts of labradorite. No. 27 of table 3 represents a thin section of this Keene gneiss, but the labradorite does not show in the thin section.

Still other local developments in the large area of "anorthosite and syenite-granite mixed rocks" are described below.

A number of small (not mappable) inclusions of Whiteface anorthosite occur in the granite along the western side of the Beech hill Whiteface anorthosite area. The borders of these inclusions have been fused and assimilated by the granite which shows curved flow-structures around the inclusions.

Interesting exposures occur in the small area of Whiteface anorthosite and syenite mixed rocks near the southeastern base of Severance hill. The rock is mostly quartz syenite (no. 49 of table 2) which contains numerous inclusions of Whiteface anorthosite. These inclusions are very irregular and usually only a few feet long without sharp boundaries against the syenite. Evidently syenite magma rising through Whiteface anorthosite caught up numerous small fragments of it, the borders having been assimilated to form Keene gneiss on small scales.

On large scales the geologic map shows two areas of Keene gneiss, one occupying about 6 square miles, and the other nearly 3 square miles, in the central portion of the quadrangle. Before the intrusion of the large gabbro stock, the two areas were probably connected with a total length of 7 miles, extending from Rogers pond to and beyond Bailey hill. These bodies of Keene gneiss lie mostly against typical Marcy anorthosite, but also, to some extent, against Whiteface anorthosite, the border facies of the anorthosite here having been very largely assimilated by the syenite-granite magma. Throughout the larger area especially, there are a good many small masses of Whiteface anorthosite, a few of sufficient size to be mapped. There are also some outcrops of fairly good granite and granitic syenite, thus showing that all the original Whiteface anorthosite was not assimilated. The main body of the rock is, however, quite typical Keene gneiss, there being

particularly fine exposures on the eastern slope of Bailey hill, and along the middle of the crest of Washburn ridge.

Certain localities of special interest in the larger area will now be described. One of these is along the brook 2 miles northeast of Bailey pond. By the trail there is a large outcrop of peculiar, variable rock. There are some small patches of Whiteface anorthosite embedded, but most of the rock has a granitoid texture and contains scattering bluish gray labradorites up to an inch long (see no. 29 of table 3). This latter rock looks much like the Cobble hill rock above described except for fewer labradorites, and it is considered to be Keene gneiss with a history similar to that on Cobble hill. Just across the brook to the east there is a big ledge of very highly foliated medium-grained granite gneiss with both the quartz and feldspar highly flattened out parallel to the foliation.

An interesting lot of rocks occur on Washburn ridge 1 mile north-northeast of Bailey pond. A little to the north of this locality (see map) a considerable body of typical Whiteface anorthosite is exposed. A few rods to the south of the anorthosite there are exposures of mostly distinctly gneissoid rocks, syenitic in appearance but containing tiny garnets and some large bluish labradorites, these latter not always being arranged parallel to the foliation. No. 30 of table 3 represents a thin section of this rock, but none of the labradorite happened to appear in the section. This rock is quite certainly Keene gneiss. Some portions of these same ledges strongly suggest rather gabbroid garnetiferous facies of Whiteface anorthosite. A few rods still farther south, typical granitic syenite is exposed as shown on the geologic map. A careful study of these ledges on Washburn ridge strongly supports the view that Whiteface anorthosite has there been acted upon by granitic or syenitic magma, some of the anorthosite having remained unaffected, some having been partially assimilated, and still others completely assimilated, while unaffected granitic syenite outcrops at the south. The actual extent of the granitic syenite here is unknown because no exposures of any kind occur for fully a mile to the south. On the crest of the southern portion of Washburn ridge, and continuing for one-half of a mile north from the area of Whiteface anorthosite (see map), a somewhat variable, medium to fine-grained, basic, syenitic-looking rock full of tiny garnets shows in good exposures. Though large labradorites are absent, this rock is thought to have

resulted from pretty thorough assimilation of Whiteface anorthosite by syenite or granite magma. Still farther north on Washburn ridge very typical Keene gneiss is well exposed.

Many fine ledges of very typical Keene gneiss occur on the eastern face of Bailey hill, no. 33 of table 3 representing a thin section of this rock.

In the smaller of the two largest areas of Keene gneiss, exposures are generally rather scarce except on the ridge north of Rogers pond where the rock toward the south contains relatively few large labradorites and suggests a gradation into granite, while toward the north the large labradorites are common and the rock appears to grade into the Marcy anorthosite.

An area about 1½ miles long of mostly Keene gneiss occupies approximately one-half of a square mile west, south and southeast of the mouth of Hewitt pond brook (see map). A number of good exposures show the rock to be somewhat variable, but it is unusually rich in hornblende and never contains phenocrysts of labradorite. In the field the rock looks much like a gabbroid facies of Whiteface anorthosite, but thin sections (nos. 46 and 48 of table 3) and the field relations cause it to be rather confidently classed as Keene gneiss.

Conclusion as to the origin of the Keene gneiss. Enough examples have been described to prove that the Keene gneiss of the Schroon Lake quadrangle has developed on small and large scales by assimilation of anorthosite by granite and syenite magmas. If we adopt Bowen's hypothesis, this Keene gneiss must be regarded as having developed by differentiation *in situ* between an overlying sheet of syenite-granite and underlying anorthosite. If one admits, as the writer does not, that syenite usually may have developed by differentiation *in situ* close upon the Marcy anorthosite, how can one imagine, in places like in the Schroon Lake quadrangle, a similar development of granite close upon the anorthosite? It might be argued that the granite magma formed at a higher level and was then forced downward. But, if so, it must have been forced downward through still lower syenitic material. Not only is the field evidence against this view, as already pointed out, but even if we grant it, we are still forced to conclude, by the obvious field facts, that the granite magma produced the transition rock (Keene gneiss) by assimilation of more or less anortho-

site, and that the Keene gneiss was not formed as a differentiate *in situ* between an overlying sheet of syenite-granite magma and underlying anorthosite.

Significance of distribution of Keene gneiss. The Keene gneiss can not be a direct differentiate of either the syenite-granite series or the anorthosite because it never occurs except on the border, or close to the contact, between the syenite or granite and the anorthosite. If we make the very simple and plausible assumption that the anorthosite was still very hot when the syenite-granite magma was intruded, or, in other words, if this latter magma was forced up comparatively soon after the development of the anorthosite, the usual strong objection to magmatic assimilation, namely, that a magma does not possess a sufficiently high temperature to raise relatively cold country rock to the point of fusion, is distinctly obviated. But the Keene gneiss is not universally present. In many cases where no Keene gneiss occurs along the borders between anorthosite and syenite or granite, it may be reasonably assumed that either the anorthosite or the syenite-granite, or both, in those places may not have been hot enough to permit assimilation.

The presence of Keene gneiss in one place and its absence from the same border nearby, may, in some cases, have been the result of unequal upward intrusion of Keene gneiss magma which originated at lower levels.

The small isolated masses of Keene gneiss some distance out from the main body of the anorthosite doubtless represent inclusions of anorthosite which were partly or completely assimilated by the enveloping syenite or granite magma.

The failure to find any considerable assimilation of Grenville either along its borders with, or where involved with, the syenite-granite series may be explained on the basis of a temperature of the Grenville too low to have permitted any more than comparatively slight assimilation by the invading syenite-granite magma. It should be borne in mind, however, as pointed out in a recent paper[1] by the writer, that local assimilation of the Grenville is known to have taken place in certain parts of the Adirondack region.

Anorthosite and Syenite-granite Mixed Rocks

A very irregular-shaped area of about 5½ square miles, including Hayes mountain, is represented on the map as anorthosite and

[1] Geol. Soc. Amer. Bul., 25:254–60. 1914.

syenite-granite mixed rocks. Enough outcrops were observed to render it certain that practically all this area was originally Whiteface anorthosite which was intruded, and more or less cut to pieces, by the syenite-granite magma. Many individual outcrops are either anorthosite or syenite or granite clearly recognizable as such, but here and there local assimilation has taken place resulting in the development of some Keene gneiss. In a few cases the rocks are admittedly of doubtful origin. Some portions of the area show few if any exposures as, for example, north and northeast of Bailey pond, and in the valley between Hayes mountain and Cobble hill. In view of the facts just stated, it has seemed impossible to represent satisfactorily the various rock types on the geologic map. A few occurrences of particular interest will be described.

Perhaps the most interesting occurrence in the area just mentioned is at the summit of Cobble hill and in the belt containing Keene gneiss which extends east-west for fully one-fourth of a mile across the southern brow of the hill (see page 46). Surrounded by typical granite, there are inclusions of Whiteface anorthosite, most of them not more than a few feet long, arranged roughly parallel to the foliation of the granite. Some of the inclusions are rather sharply separated from the granite, many of them had their borders assimilated, while still other anorthosite caught up in the granite magma was completely assimilated to form Keene gneiss.

The interesting lot of rocks on the steep hillside one-half of a mile north-northwest of Bailey pond has been described above under the caption "Keene gneiss."

A big ledge in the brook at the old road crossing 1 mile west-northwest of the summit of Hayes mountain shows typical Whiteface anorthosite closely involved with granite with apparently slight development of Keene gneiss.

The margins of the small body of Whiteface anorthosite separately mapped on top of Hayes mountain appear to have been assimilated and close to its borders the anorthosite carries quartz (no. 18 of table 1).

The small area of anorthosite and granite mixed rocks on top of Wilson mountain shows numerous little inclusions of Marcy anorthosite in the granite, these having been described in the above discussion of the anorthosite. The relations are shown in figure 1.

In the small area near the southeastern base of Severance hill, syenite contains numerous inclusions of Whiteface anorthosite. These inclusions are usually only a few feet long and very irregular with their borders more or less assimilated by the syenite.

Gabbro and Metagabbro(?)

Distribution. These gabbro and metagabbro (?) bodies are, in most respects, very similar to those of the North Creek quadrangle next to the south which have been rather fully described by the writer in his report on the *Geology of the North Creek Quadrangle*[1] and also in the Journal of Geology, volume 21, pages 160–80. On the accompanying Schroon Lake geologic map, twenty-five gabbro masses are represented, all but four of these lying wholly within the quadrangle. They are well scattered over the southeastern two-thirds of the quadrangle, but not one has been found within the area of Marcy anorthosite. A possible explanation of their absence from the anorthosite area is given above in the discussion of the anorthosite. As usual in the writer's experience in the Adirondacks, these gabbro masses appear to have rounded to elliptical ground plans and very steep walls. The variation in length of the areas of outcrop is from one-fifth of a mile or less to 3 miles. In a few of the areas but one or two outcrops could be located.

A striking feature of the distribution is the fact that the three largest bodies of the quadrangle lie along the border of the Marcy anorthosite. Kemp's Elizabethtown map shows a similar distribution of the largest gabbro masses there. Also on Ogilvie's Paradox Lake map the largest mass of gabbro occurs along the anorthosite border. This remarkable distribution of the gabbro bodies with reference to the anorthosite may be merely a coincidence, or it may have a real significance. If the latter, the writer can think of no very plausible explanation.

Age. Most or all of the gabbro is younger than the Grenville, anorthosite and syenite-granite series (1) because of the intrusive contacts against rocks of those series, (2) because dikes of gabbro extend into rocks of those series, and (3) because inclusions rep-

[1] N. Y. State Mus. Bul. 170.

resenting fragments of all three series occur in the gabbro. Some of the metagabbro (?) is quite certainly older than the syenite-granite.[1]

Pegmatite dikes and certain small aplite dikes have been observed as sharply defined intrusions in the gabbro. The diabase dikes are later intrusions than the gabbro as proved by their distinctly finer grain, and the fact that one actually cuts the gabbro in the northern part of the North Creek quadrangle. It is therefore evident that at least three very distinct minor intrusions succeeded the gabbro intrusions of the quadrangle.

Megascopic features. The typical nonfoliated gabbro is readily distinguished from all the other rocks of the quadrangle. Such rock makes up the main or interior masses of nearly all the stocks, especially the larger ones. It is medium to moderately coarse grained, dark gray to almost black where fresh, and it weathers to a deep brown. The plagioclase feldspar varies in color from a light gray to a dark bluish gray. A diabasic texture is usually more or less well developed, this being particularly striking in the coarser grained facies. Minerals recognizable with the naked eye or hand lens include plagioclase, pyroxene, hornblende, ilmenite (or magnetite) and nearly always biotite and red garnet.

Variations from the typical nonfoliated gabbro just described are common, one of the most abundant being highly foliated border facies (usually amphibolite) which do not show a diabasic texture. Taken by themselves, some of the amphibolitic border facies are very difficult to distinguish from certain Grenville hornblende gneisses, or even from certain very gneissoid gabbroid facies of the Whiteface anorthosite. Nearly always, however, the mode of occurrence or the gradation into more typical gabbro renders certain the recognition of the gneissoid border facies of the gabbro (figure 4). Even the more typical inner portions of the gabbro stocks show many notable variations in structure, texture and mineralogical composition as pointed out below in the special descriptions.

Microscopic features. In the following table the mineral contents of the gabbro is represented by thin sections of samples from several of the areas.

[1] Recent work by the writer in the Lyon Mountain quadrangle has shown that most of the gabbro and metagabbro are there older than the syenite-granite series which leads to the suspicion that some of the Schroon Lake quadrangle gabbro may also be older but definite evidence is lacking.

Table 4 Thin sections of gabbro and diabase

	Slide no.	Field no.	Orthoclase	Labradorite	Olig. to lab.	Hypersthene	Diallage	Hornblende	Biotite	Olivine	Magnetite	Pyrite	Apatite	Zircon	Calcite (Sec.)	Garnet
Gabbro	39	2 c 2	8	....	47	20	....	15	3	....	1	little	little	little	1	5
	40	9 h 1	15	....	45	8	....	25	2	....	½	......	½	little	....	4
	41	9 h 4	....	40	....	24	5	....	5	8	3	......	......	......	....	15
	42	12 c 4	....	45	....	26	....	....	6	4	1	little	......	......	....	18
Diabase	43	15 j 3	....	48	....	30	....	6	....	....	6	......	......	......	....	10
	44	16 j 6	....	....	40	25	10	3	....	....	4	......	little	......	....	18

No. 39, 1 mile southeast of Minerva; no. 40, 1¾ miles east of Bailey pond and near the mapped inclusion of granite; no. 41, middle of Texas ridge gabbro area; no. 42, 1½ miles northeast of Lester dam; no. 43, top of Saywood hill; no. 44, one-third of a mile north of summit of Saywood hill.

In the above table, nos. 41 and 42 are more typical of the gabbro of the quadrangle, while nos. 39 and 40 are rather more special or acidic facies. The more normal rock is therefore an olivine-bearing hypersthene gabbro or norite. The garnet, which is no doubt of secondary origin, mostly forms granulated borders about granulated hypersthene. In slide no. 41 the biotite mostly forms reaction rims about magnetite, and granulated garnet forms rims around granulated hypersthene in nos. 41 and 42. Nearly colorless diallage in no. 41 exhibits wonderful parting and schillerization inclusions. The labradorite of nos. 41 and 42 are filled with tiny dustlike dark inclusions.

Special descriptions. The Texas ridge mass is the finest large scale example of a gabbro stock in the quadrangle. It covers an area of approximately 3½ square miles. An almost continuous outcrop occurs along the whole crest of the ridge. Near the southern end of the ridge a considerable mass of well-foliated pinkish gray granite forms an inclusion in the gabbro (see map). Immediately south of this inclusion the gabbro is notably variable, being mostly moderately foliated, but some big ledges are medium grained and very massive. None of this rock exhibits a diabasic texture. No. 42 of the table shows the mineral contents of a thin section of the more common rock, and this is seen to be a distinctly acidic or dioritic facies even carrying considerable orthoclase. The near-

ness of this facies to the inclusion of granite from which it is not very sharply separated, taken in the light of various observations made by the writer on the North Creek quadrangle gabbro, strongly supports the view that this acidic facies of the gabbro was produced by assimilation of some granite during the intrusion of the gabbro magma. In this same vicinity some outcrops of rather coarse-grained, nonfoliated gabbro show 5 to 10 per cent red garnets ranging in diameter from a millimeter or two to one-third of an inch. These variations all occur within a stone's throw. Just north of the granite inclusion, the gabbro is medium to fine grained, very gneissoid, and relatively richer in feldspar. Gabbro similar to this latter also appears on the ridge crest about three-fourths of a mile northeast of the granite inclusion; otherwise the many exposures along the whole ridge crest are very typical, medium grained, nonfoliated gabbro with diabasic texture. No. 41 of table 4 shows the mineral content of a thin section of this typical gabbro. Similar gabbro outcrops in considerable force near the extreme southwestern end of the area, and also on the ridge along the eastern side of the area.

The Cheney pond stock is the second largest. It covers nearly 3 square miles. There are many good exposures. Most of this gabbro is very typical in every way, being medium to moderately coarse grained, nonfoliated, and possesses a diabasic texture. No. 42 of table 4 shows the minerals contained in a thin section. Good exposures of the amphibolitic border facies occur along the southern border between the pond and the old road, on the little island in the pond, and where the river enters the pond. In a field a few rods south of where the river enters the pond, a sharply defined 8-inch inclusion of typical Whiteface anorthosite occurs in the gneissoid gabbro. A body of granite large enough to be mapped occurs as an inclusion in the gabbro 1¼ miles northeast of the Lester dam. Whether or not the gabbro near this inclusion is more acidic than usual was not determined.

The large stock partly shown within the map limits northwest of Cheney pond is mostly very typical gabbro with considerable amphibolite developed as a border facies. In a field a few rods north of the house (where the trail leads off) there are some very interesting ledges showing amphibolitic gabbro and Whiteface anorthosite rather intimately associated.

A number of good exposures show the gabbro of the stock about a mile southeast of Minerva to be mostly medium grained and massive with only poor development of diabasic texture. Locally

a gneissoid structure is clearly evident. Much of this rock well exhibits the peculiar mottled appearance so often seen in those Adirondack gabbros which are relatively free from diabasic texture and foliation, this mottling being due to the irregular distribution of black minerals through the more or less granulated mass of feldspar. No. 39 of table 4 gives the mineral content of a thin section. This is a distinctly acidic facies and, like the local acidic facies of the Texas ridge gabbro above described, may have resulted from assimilation of granitic material by the gabbro.

The small gabbro stock on the hill one-half of a mile west of Irishtown contains a 10-foot inclusion of thin-bedded Grenville quartzite.

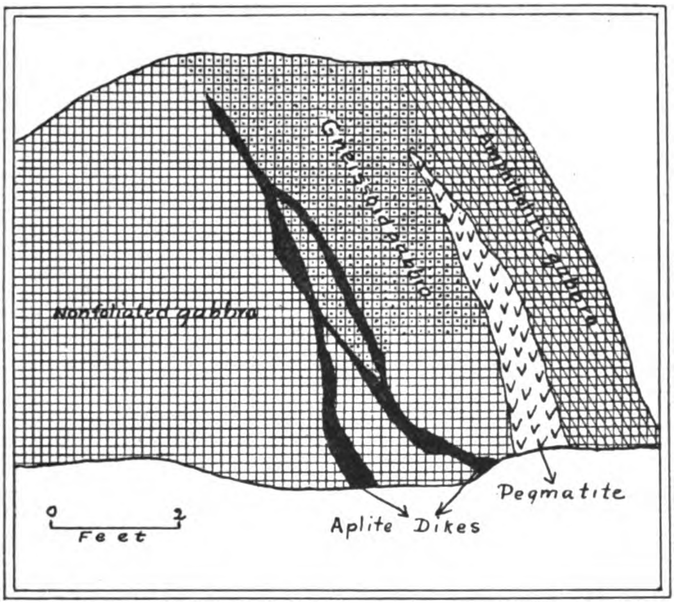


Fig. 4 A small exposure showing three facies of gabbro at the eastern margin of the Oliver hill stock. The gabbro is cut by aplite and pegmatite dikes.

Some interesting features were observed in connection with the Oliver hill gabbro stock. Just south of the summit of the hill the gabbro sends three dikes into the granite. None of these dikes is more than a few rods wide, and one is amphibolitic. At the extreme eastern end of the stock a small outcrop shows three facies of gabbro — one nonfoliated, another highly foliated, and a third

amphibolitic — cut by several white, fine-grained, aplite dikes and a pegmatite dike. The relations are brought out in figure 4.

The stock southeast of North pond shows large developments of very gneissoid to amphibolitic facies of gabbro, especially in its eastern portion. A ledge of rather typical, medium-grained gabbro just east of the brook one-fourth of a mile north of its junction with Rogers brook, contains many lenses and strips of nearly white Whiteface anorthosite as inclusions with parallel arrangement. A number of small faults intersect the ledge. The relations are brought out in figure 5. On the small hill in the western part of the area, typical nonfoliated gabbro is involved with

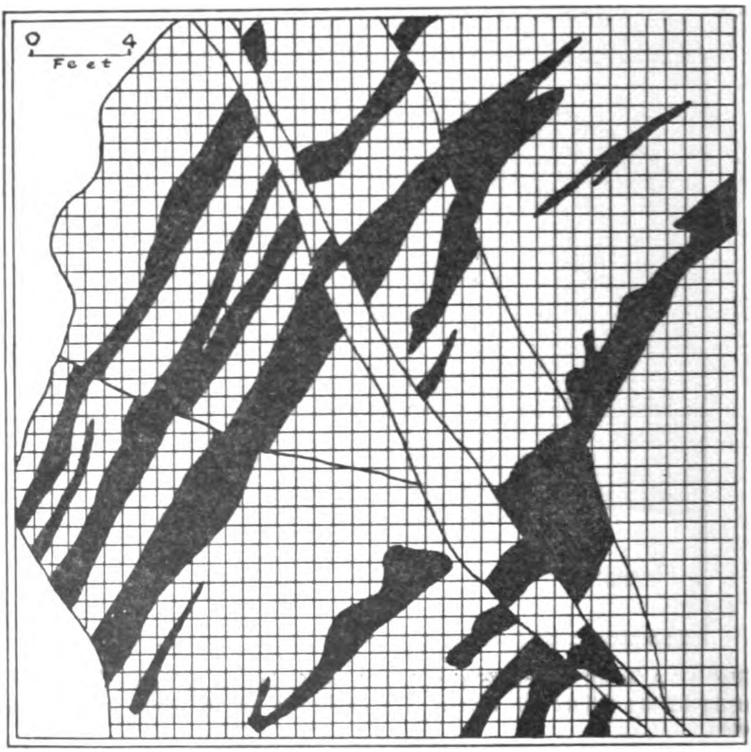


Fig. 5 A sketch of part of an outcrop near the brook at the southern margin of the gabbro stock southeast of North pond. The normal gabbro (cross-lines) contains many parallel strips of Whiteface anorthosite (black), and the whole is intersected by several minor faults.

well-foliated gabbro, these two facies forming zones or belts not very sharply separated from each other. This foliation is very clearly a flow-structure due to magmatic currents, with the wavy

flow-lines clearly preserved. Further, these well-foliated zones bear a distinct resemblance to the gneissoid or amphibolitic border facies of the gabbro already described, and thus we have here evidence strongly supporting the view that the foliation of the amphibolitic border facies of the gabbro is really essentially the result of magmatic flowage.

The northern part of the small stock near the southern end of Ledge hill is typical gabbro cut by one small pegmatite dike and several small aplite dikes.

Two small masses, one on Cobble hill and the other three-fourths of a mile northwest of Loch Muller are hornblende gneiss (metagabbro?) quite certainly older than the granite.

Aplite and Pegmatite Dikes

Aplite. Aplite dikes were observed in only a few localities but probably others occur within the quadrangle. These are represented only in a general way on the geologic map. They probably do not all belong to the same period of intrusion.

The best display of aplite dikes is on Wilson mountain. These are all medium to fine grained and none are foliated, neither do they show any notable difference in coarseness of grain between center and sides. On the western summit of the mountain a number of small aplite dikes, none over a foot wide, cut clearly gneissoid, coarse-grained, pinkish granite. These do not have very sharp boundaries against the granite. This fact, together with their uniform medium-grained texture, suggests that these aplite dikes were intruded under fairly deep-seated conditions not long after the intrusion of the granite, or at least before the granite cooled very much, so that the aplite magma was able to blend with the walls of the granite country rock.

On the eastern summit of Wilson mountain, numerous aplite dikes very similar to those just described, and with a maximum width of 4 feet, cut gneissoid medium-grained granite also without very sharp contacts.

The small mass of anorthosite and granite mixed rocks on Wilson mountain (see map) is cut by a number of medium-grained aplite dikes, the widest being 5 inches, and all showing rather sharp contacts against the granite.

Another locality is near the southern end of Ledge hill where several aplite dikes very sharply cut the small gabbro stock. The

largest is 5 inches wide, visible for 10 or 12 feet, and has a branch bearing off abruptly at right angles. Another is 2 inches wide and traceable for 20 feet in the gabbro. None of these dikes could be traced into the surrounding granite. In certain respects these aplite dikes are quite different from those on Wilson mountain. Most of the dike material is fine grained, particularly so at the margins, but this grades into a medium-grained, narrow, middle portion which is very persistent. The dike rock is somewhat weathered and of light-brown color, this latter probably due to stains from iron-bearing minerals in the gabbro. Because these dikes sharply cut the gabbro, which is distinctly later than the granite, and because of their chilled margins, it is believed that they were intruded considerably later than the aplite dikes on Wilson mountain above described. A thin section shows the following mineral percentages: microperthite, 65; oligoclase, 1; quartz, 20; diallage, 12; magnetite, 2; and very little zircon. The thin section shows a granitoid texture and no granulation.

At the eastern end of the Oliver hill gabbro stock a few branching, fine-grained, white, aplite dikes a few inches wide cut the gabbro, the relations being shown in figure 4. Although these dikes are white and do not have distinctly coarse portions, it is probable that they were intruded at about the same time as those on Ledge hill.

Pegmatite. A number of pegmatite dikes were observed in the granite on top of Ledge hill for one-half of a mile northward from the gabbro stock. None of these is more than 2 feet wide, and they all cut sharply across the foliation of the granite very irregularly. Near the eastern margin of the gabbro stock a very small pegmatite dike cuts across the foliation of the granite, and nearby another cuts the gabbro.

On the western summit of Wilson mountain near the aplite dikes, a number of very small pegmatite dikes sharply cut the granite. Near the eastern margin of the Grenville area on the western face of Wilson mountain, several small pegmatite dikes cut a mixture of Grenville and granite.

At the eastern end of the Oliver hill gabbro stock the same ledge which contains the aplite dikes (see figure 4) is also cut by a small pegmatite dike which is without very sharp contacts against the gabbro. Whether this is older or younger than the aplite was not determined.

Pegmatite dikes are scarcer in the Schroon Lake quadrangle than is usual in the Adirondack region. Not one was observed in

the large body of anorthosite. In certain other quadrangles, like the Blue Mountain, the writer has found at least two sets of pegmatite dikes notably different in age, one occurring in the form of narrow masses essentially parallel to the foliation of, and not very sharply separated from, the inclosing syenite or granite, and the other, generally coarser grained, cutting across the foliation of, and in sharp contact with, syenite or granite. The second set is quite certainly the younger, and probably all the observed pegmatites in the granites of the Schroon Lake quadrangle belong with the younger set.[1]

Diabase Dikes

Diabase dikes were observed in nine localities within the quadrangle, but doubtless others exist. They are represented on the geologic map. Most of these are like the usual diabase dikes of the Adirondacks, more particularly like those of the North Creek quadrangle described by the writer. Unlike the gabbro, aplite, and pegmatite, several of the diabase dikes cut the anorthosite. The diabase probably represents the latest Precambrian intrusion in the Adirondack region as shown by the fine-grained texture and usually very distinct chilled borders, and also by the fact that a diabase dike actually cuts one of the late pegmatite dikes in the adjoining North Creek quadrangle. A diabasic texture is not always evident to the naked eye, but in thin section it is generally recognizable. None are porphyritic, but several show very distinct magmatic flow-structure foliation. All have sharp contacts against the country rocks.

About one-fifth of a mile north of the old graphite mine at the western base of Catamount hill, a small typical diabase dike with strike N 40° E cuts Grenville gneisses.

A diabase dike 2 feet wide with strike S 20° W is well exposed in the syenite of the quarry one-half of a mile east-northeast of South Schroon.

In a ledge of gneissoid granite by the road 1 mile west of Schroon Lake village, there are several small dikes varying in width from 2 to 8 inches. One is faulted 6 or 8 inches at two places.

A very typical diabase dike with a maximum width of 40 feet and strike N 20° E is clearly traceable for fully one-half of a mile in the Whiteface anorthosite about 1½ miles north-northwest of

[1] Certain Adirondack pegmatites are discussed by the writer in a recent paper (Jour. Geol., vol. 27, no. 1, 1919) where it is shown that some pegmatites developed as satellites of the cooling magmas of the late gabbros.

Schroon Lake village. At one place many small off-shoots from the dike were observed to cut sharply the Whiteface anorthosite.

A dike 6 inches wide with strike N 20° E cuts Whiteface anorthosite at the summit of Severance hill.

A dike of very typical diabase with maximum width of 40 feet cuts pinkish granite for one-quarter of a mile across the top of the little hill 1¼ miles due west of Grove Point.

Three dikes of particular interest cut typical Marcy anorthosite at the summit of Saywood hill. They vary in width from 6 inches to 1½ feet and strike N 20° W. These dikes all show rather distinct magmatic flow-structure foliation. Diabasic texture is absent, and the fresh rock is dark gray with numerous black ferro-magnesian minerals each from 1 to 3 millimeters long. A close inspection reveals many tiny red garnets. In thin section (no. 43 of table 4) this rock is seen to be a hypersthene diabase.

Near the top of the hill one-third of a mile due north of the summit of Saywood hill there are two diabase dikes, one 15 feet wide and the other 2 feet wide, traceable for a number of yards in sharp contact with the Marcy anorthosite. The narrower dike is probably a branch of the wider one. These dikes have a good diabasic texture, and they are finer grained toward their margins. Myriads of tiny red garnets are visible under the hand lens. They show no foliation. A thin section (no. 44 of table 4) shows these dikes to differ from those on Saywood hill by carrying 10 per cent diallage, and oligoclase to labradorite instead of labradorite alone.

On the ridge one-half of a mile north-northwest of Blue Ridge village a dike 2 feet wide sharply cuts the Marcy anorthosite with strike N 40° W. This dike looks almost exactly like those on Saywood hill above described.

PALEOZOIC ROCK OUTLIERS

Two outliers of early Paleozoic strata occur within the Schroon Lake quadrangle. One of these, in and near the village of Schroon Lake, has long been known, but the other, 1½ miles southwest of the village, was located by the writer in 1916. During 1917 the writer discovered another outlier in the valley of Schroon river 7 miles north of Schroon Lake village. The outliers at and near the village are of particular geological significance, having been formerly connected with the main body of early Paleozoic strata of both the Champlain and Mohawk valleys, but now being isolated masses from 13 to 16 miles from the Champlain valley strata.

Potsdam Sandstone Southwest of Schroon Lake Village

This area of Potsdam sandstone lies 1½ to 2 miles southwest of Schroon Lake village, or about 1 mile west to southwest of Grove Point. It was discovered by the writer in 1916. Just southwest of the forks of the road three-fourths of a mile west of Grove Point, there are four exposures, three of them in the road and the other just across the fence to the south of the road. The largest outcrop is several rods long. Paced at right angles across the strike of these exposures the distance is 45 yards. Since the dip is west 5°, a thickness of about 12 feet of the sandstone occurs here with neither top nor bottom visible. The strata strike N 30° E. In the brook just north of these exposures there are many angular fragments of the sandstone, but still farther north neither fragments nor outcrops occur, so that the northern limit of the area must be about as indicated on the accompanying geologic map. For fully one-half of a mile to the south-southwest, within the area mapped, a number of small exposures of the sandstone were observed, and also hundreds of angular fragments up to several feet across. Hundreds of angular fragments of the sandstone also occur on both the north and south sides of Thurman pond, but a careful search failed to reveal an outcrop. Probably these are simply fragments in the glacial drift.

In all the outcrops the rock is in every way typical Potsdam sandstone, being gray, well stratified, often cross-bedded, and not very coarse grained. The layers are generally from a few inches to a foot thick. No fossils were found. That these beds are very close to the bottom of the Potsdam formation is evident from the fact that granitic syenite, the immediately underlying rock, outcrops close by on the east (see map). A fault passes along the foot of the hills just west and this probably marks the western boundary of the sandstone, though no exposures of any kind occur close to the fault on its east side.

Little Falls (?) Dolomite in and near Schroon Lake Village

Description of occurrences. In a paper dealing with the iron ores of northern New York published by C. E. Hall[1] in 1879, mention is made of this outlier.

In his *Preliminary Report on the Geology of Essex County,*[2] Professor Kemp briefly describes the outlier and discusses its significance.

[1] N. Y. State Mus. Rep't 32, p. 130–40. 1879.
[2] N. Y. State Geol., 15th Annual Rep't, 1895, p. 596–98.

Since no detailed study of this outlier has yet been published, the observations made by the writer during the summers of 1916 and 1917 are here somewhat fully recorded.

The dolomitic limestone is well exposed for a distance of fully 100 feet along the shore of the lake just north of the steamer landing in the village. Plate 7 shows the general appearance of the outcrop. The strike of the beds is N 50° E and the dip N 23°. A detailed measured section follows:

	Feet	Inches
6 Dolomitic limestone without chert...............	3	0
5 Dolomitic limestone with much dark chert in the form of irregular bunches up to 6 inches or even a foot long..................................	3	8
4 Dolomitic limestone without chert or calcite......	2	0
3 Dolomitic limestone much like 2 below, except that chert is less conspicuous and not in layers.	3	8
2 Dolomitic limestone with much chert mostly in thin layers, but some in irregular bunches. Also numerous veinlets and bunches of calcite, some of which is dark to black with bituminous matter. On the weathered surface there are signs of stratification surfaces separating the rock into thin layers	5	6
1 Dolomitic limestone with considerable chert (below the water)	2	
Total..................................	19	10

The dolomitic limestone of this section is dark gray weathering to light gray, crystalline, fine grained and compact in texture. It contains numerous rounded quartz-sand grains not visible to the naked eye, but bits of the rock treated with hot hydrochloric acid leave considerable residues of the fine quartz-sand grains. Weathered surfaces of the rock are generally rough and deeply pitted due to more rapid removal of the irregular calcite bunches.

The greatest thickness of limestone exposed in any one section is in the bed of Rogers brook between its mouth and the main road. These beds strike N 50° E and dip N 23°, and the stream descends about 25 feet as a cascade over the ledge. The approximate thickness of this section, based upon careful pacing (160 feet) across the strike, is 85 feet. There are several intervals in the section, a thickness of 5 or 6 feet being concealed in one place.

Plate 7

W. J. Miller, photo, 1916

The ledge of Little Falls (?) dolomite by the Lake shore a few rods north of the steamer landing in Schroon Lake village

Most of the beds are from 6 inches to 2 feet thick with stratification surfaces between them very evident. Such beds are in nearly every way like those above described as occurring just north of the steamer landing. Chert is often present. Kemp, in the paper above referred to, states that "thin sections of the chert merely exhibit a brown, nearly isotropic base with numerous rhombohedra of calcite or dolomite scattered through it." Some relatively thin layers are, however, very sandy. Considering the strike, dip and location of this section and the one just north of the steamer landing, it is quite clear that the latter underlies the former with an intervening thickness not definitely known, but probably about 10 feet. Adding this 10 feet to the combined thickness of the two known sections, the thickness of the dolomitic limestone underlying this part of the village is at least 115 feet, with neither top nor bottom visible.

Another excellent outcrop occurs in the quarry in the northeastern portion of the village. This exposure is about 150 feet long (1917) parallel to the strike which is N 50° E. At the north end the dip is W 34°, and at the south end W 30°. A thickness of 28 feet was measured across the southern end of the quarry, and 30 feet across the northern end. The rocks are very distinctly bedded in layers a few inches to 2 feet thick, usually 1 to 2 feet. Plate 8 gives a good idea of the appearance of the rock in the quarry. Except for a few thin, black shale and sandy shale partings, the rock is all dark gray, fine grained, crystalline, dolomitic limestone very similar to that of the other localities above described. Scattering veinlets and bunches of calcite, often dark with organic matter, are common, but no chert was observed. The rock weathers to a light gray. Judging by the strike, dip and location, this quarry section probably lies in part at the horizon of the upper beds of the Rogers brook section, but mostly above it. On this basis, and barring the possibility of an intervening fault, a thickness of something like 20 feet should be added to the thickness above determined for the southern part of the village. This would make the total thickness of dolomitic limestone under the village approximately 135 feet, with neither top nor bottom exposed.

On the lake shore one-third of a mile southwest of the mouth of Rogers brook, there are two small exposures of dolomitic limestone in beds from 6 inches to 1 foot thick, with a total thickness of 10 feet. These beds, with strike N 60° E and dip W 7°, are about on a line with, and look much like, the beds at the steamer

landing. On the weathered surfaces the rock is very rough and deeply pitted due to dissolving out of calcite bunches.

A very careful search southwest, west and north of the village failed to bring to light any other exposure of either dolomitic limestone or Potsdam sandstone than those above described, the glacial drift masking the underlying rocks to the foot of the hills (see map). Neither does the drift in this area anywhere carry angular fragments of either sandstone or dolomite which would strongly suggest the existence of concealed ledges. In fact, even rounded fragments are very rare. An angular fragment of typical Trenton limestone with fossils just west of the southern end of Thurman pond suggests such limestone in place, either now or just before the Ice age, not farther south than the vicinity of Schroon Lake village.

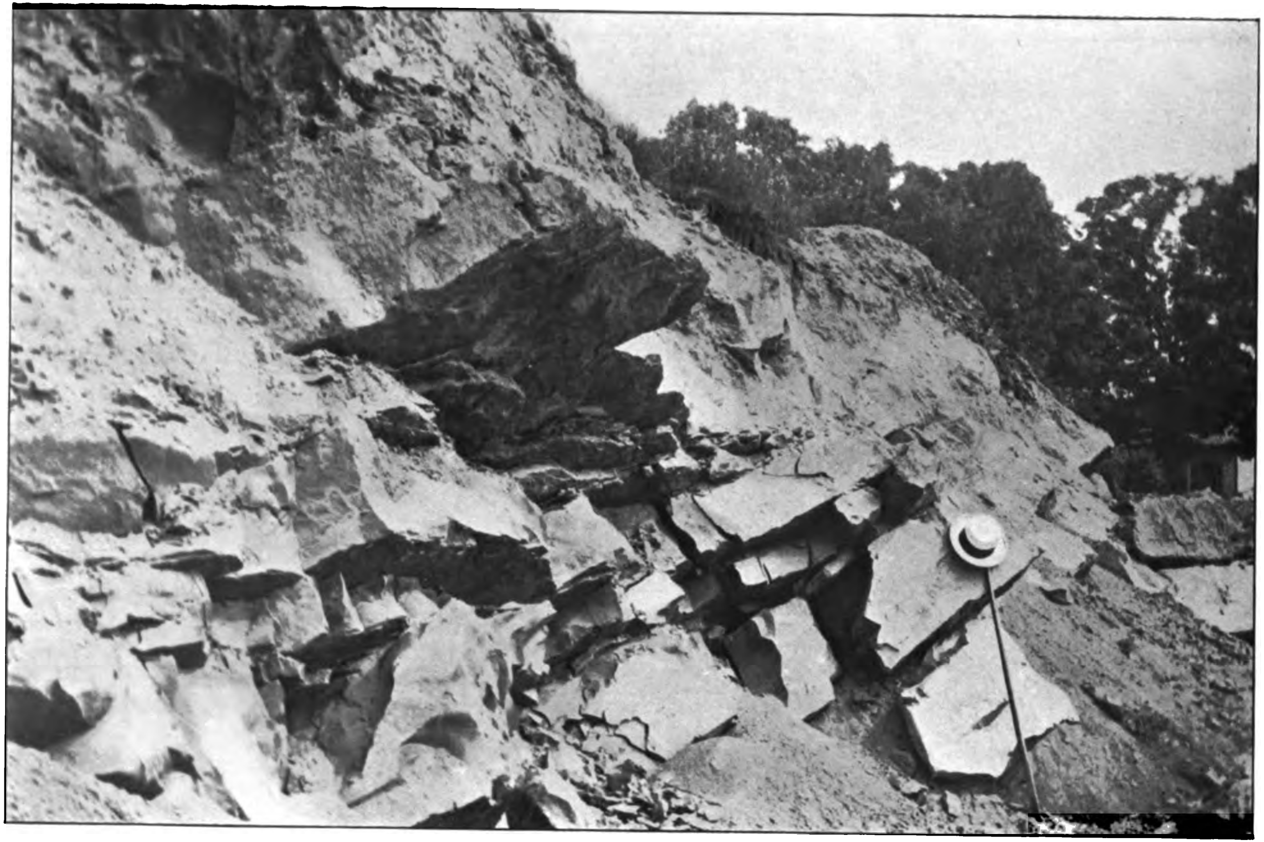
Age of the dolomite. A diligent search through the dolomitic limestone of all the exposures failed to reveal any remains of organisms. Kemp, in his report of 1895, likewise states that he was unable to find fossils. This absence of fossils, combined with the isolation of the limestone at Schroon Lake, renders it practically impossible to correlate very definitely or determine the age of this limestone. C. E. Hall, in the paper above mentioned, makes the following very brief statement: "At Schroon Lake village the Chazy limestone occurs with fossils. The outcrops are not extensive, being covered by a sand clay deposit." With Hall, however, consideration of the Schroon Lake outlier was an incidental matter and more than likely, on the basis of general resemblance, the Schroon Lake limestone was classed with the fossiliferous Chazy limestone of the Champlain valley, the fossils having been assumed to be present.

Kemp[1] notes the close resemblance of the Schroon Lake limestone "to the cherty magnesian limestones that are undoubtedly Calciferous (in age) and nonfossiliferous on Lake Champlain," and with some hesitation he correlates them. The writer believes Kemp essentially correct in this view. But the old Calciferous formation, many hundreds of feet thick in the Champlain valley, was then considered to be wholly Ordovician in age, with cherty beds in the lower portion.

As a result of more recent work, important changes of view regarding the old Calciferous formation have taken place, these changes being concisely stated by Cushing[2] as follows: "The name

[1] 15th Annual Rep't N. Y. State Geol., 1895, p. 597.
[2] N. Y. State Mus. Bul. 169, p. 42. 1914.

Plate 8



W. J. Miller, photo, 1916

A near view of Little Falls (?) dolomite in the quarry in the northern part of Schroon Lake village. Glacial drift rests upon the rock.

'Calciferous' was originally applied to the considerable thickness of dolomitic rocks which overlies the Potsdam sandstone in the Champlain and Mohawk valleys. Later on Clarke and Schuchert replaced this by the name Beekmantown, and to the rather unfossiliferous phase of the formation in the Mohawk valley gave the local name of Little Falls dolomite. . . . Recent work of Ulrich, Ruedemann and Cushing showed that the Little Falls dolomite of the Mohawk valley was the equivalent" of the lower portion of the Champlain Beekmantown, and that it was really separated from the overlying Beekmantown by unconformity and graded through transition beds (Theresa) into the underlying Potsdam sandstone.

The Schroon Lake and Little Falls dolomitic limestones are almost exactly alike in nearly every way, both being very largely dark-gray, fine-grained, crystalline, usually rather thick bedded, dolomitic, sandy limestones with considerable chert as irregular masses and irregular bunches of crystalline calcite at certain horizons, and almost, or entirely, devoid of fossils. Cavities containing very clear quartz crystals, so characteristic of certain horizons of the Little Falls dolomite of the Mohawk valley, were not observed at Schroon Lake, but it is quite possible either that the proper horizons are not there exposed or that such cavities may never have formed there. It is also of interest to note that Potsdam sandstone, the rock with which the Little Falls dolomite is almost invariably affiliated, outcrops to the southwest of the Schroon Lake dolomite.

All points considered, then, it is very probable that the Schroon Lake dolomitic limestone should be regarded as Little Falls (Upper Cambrian) dolomite.

Newly Found Outlier in the Paradox Lake Quadrangle

During the summer of 1917 the writer discovered an outlier of Paleozoic rock in the Schroon river valley of the Paradox Lake quadrangle 2½ miles due north of Schroon Falls, or 7 miles north of Schroon Lake village. It lies west of the river and only one-fourth of a mile east of the boundary of the Schroon Lake quadrangle. In an area of about 2 acres there are exposures of dolomite in fairly thick beds resting upon sandstone, a total thickness of not over 25 feet being visible. These strata lie in practically horizontal position. Whether this is true Little Falls dolomite resting upon Potsdam sandstone, or the rocks represent transition

(Theresa) beds between the two, the writer does not know. In any case, it is quite certain that the rocks of this outlier are to be classed with the Potsdam-Little Falls series in general.

Significance of the Outliers

The significance of the outliers of Paleozoic rocks at and near Schroon Lake should be considered in the light of all the outliers of Paleozoic strata in the southeastern portion of the Adirondack region. Altogether they afford positive evidence that early Paleozoic sea waters spread over all or nearly all of that region. All the definitely known outliers which occur well within the area of Precambrian rocks of the southeastern Adirondacks are as follows:

1 A small exposure of Potsdam sandstone near the southwestern corner of the Elizabethtown quadrangle.

2, 3, 4 Three small areas of Potsdam sandstone along the eastern side of the Paradox Lake quadrangle.

5 Little Falls (?) dolomite at Schroon Lake village.

6 Potsdam sandstone 1½ miles southwest of Schroon Lake village.

7 A small area of sandstone and dolomite belonging to the Potsdam-Little Falls series 2½ miles due north of Schroon Falls in the Paradox Lake quadrangle.

8 A small mass of Potsdam sandstone 1½ miles west of North River village in the Thirteenth Lake quadrangle.

9 A small body of sandstone and dolomite belonging to the Potsdam-Little Falls series 1 mile west of High Street village in the northern part of the Luzerne quadrangle.

10 A large outlier, several miles long, in the Sacandaga river valley at Wells in the Lake Pleasant quadrangle where are well-exposed Potsdam sandstone, Theresa transition beds, Little Falls dolomite, Black River (Lowville) limestone, Glens Falls limestone and Canajoharie (Trenton) shale.

11 A considerable outlier showing Theresa beds, Little Falls dolomite, and Black River limestone between 1 and 3 miles north of Hope in the Sacandaga valley of the Lake Pleasant quadrangle.

Of these, nos. 6, 7, 9 and 11 have been discovered by the writer during the last 6 or 7 years. Besides the above, a number of outliers occur close to the main body of Paleozoic strata.

Wherever detailed geologic maps have been made in the southeastern Adirondacks, the region is shown to be literally cut to

pieces by numerous normal faults, the most prominent of which usually strike from north-south to northeast-southwest, with known displacements ranging from a few hundred to 2000 feet or more. It is important to note that the outliers above listed, except possibly nos. 2, 3 and 4, lie on the downthrow sides of such faults. Thus a prominent fault bounds the Schroon Lake valley on the west. It appears, therefore, that the valleys containing these outliers have been largely produced by faulting, and that the Paleozoic strata formerly lay at much higher levels, that is, the general level of the surface of Precambrian rocks of the region.

Were the early Paleozoic sediments deposited in embayments or estuaries of the sea extending well into the area of Precambrian rocks, or were they deposited as a general mantle over the Precambrian rocks of the whole southeastern Adirondack region? As a result of detailed studies it has been established that the southern half or two-thirds of the Adirondack area was, by the beginning of Potsdam time of the late Cambrian period, worn down to the condition of a peneplain upon whose surface only a few minor knobs or prominences existed. This being the case, notable embayments or estuaries could scarcely have existed. Still further evidence against the embayment idea comes out of the character of the sediments. Thus the rocks of the outliers, including those of Schroon Lake and Wells, are distinctly marine formations of exactly the same character as those of the same age in the general Paleozoic rock area of the Champlain and Mohawk valleys. Estuarine deposits would show certain distinct local variations and hence the very uniformity of the marine sediments in the outliers precludes the possibility of their deposition in estuaries. Thus we conclude that when the early Paleozoic, or more precisely late Cambrian, sea encroached upon the southeastern Adirondack area a general mantle of sediments was deposited over the whole region including much at least of the area of the Schroon Lake quadrangle, and that, subsequent to the emergence of the region, normal faulting took place whereby portions of the Paleozoic strata were, in many places, carried so far down that remnants have to this day been protected against complete removal by erosion. Thus we explain the existence of the outliers of early Paleozoic marine strata in the Schroon valley.

Early and Middle Cambrian strata are unknown in northern New York, and there is no evidence that early and middle Cambrian seas ever spread over any portion of that area. But with the late

Cambrian the case is different. The first deposit to form in the late Cambrian sea was the Potsdam sandstone which is well represented in the St Lawrence, Champlain and Mohawk valleys, these regions all having been submerged under the Potsdam sea. In the southeastern Adirondacks the Potsdam sea certainly extended in as far as Wells (southern Hamilton county), North River (northwestern Warren county), and Schroon Lake (southern Essex county), because small outlying masses of Potsdam sandstone occur in those localities, having been formerly connected with the larger areas around the Adirondacks as above explained. The Potsdam sea surrounded and more or less lapped over on the borders of the Adirondack region, particularly the southeastern portion. There is no evidence that the interior of the Adirondack region was submerged, but rather it almost certainly formed a large island in the Potsdam sea.

Marine conditions continued with the deposition of alternating layers of sandstone and dolomite upon the Potsdam. This is called the Theresa formation. After still greater submergence, the important formation known as the Little Falls dolomite was deposited layer upon layer to a thickness of usually several hundred feet in the comparatively clear waters of the latest Cambrian sea. The Little Falls sea swept all around the Adirondacks. Occurrences of the formation in the outliers at Wells (Hamilton county) and at Schroon Lake prove that the Little Falls sea extended well over the eastern Adirondack area, including much at least of the Schroon Lake quadrangle. Map figure 6 graphically shows the approximate relations of land and water during late Cambrian time.

The Cambrian period closed with all of northern New York above sea level, but early in the Ordovician period a submergence set in, reaching a maximum about the middle of the period. Even at the time of maximum submergence in the Middle Ordovician, the best evidence points to the existence of a considerable island comprising the interior of the Adirondack region (see map figure 6).[1] Mid-Ordovician strata at Wells indicates the presence of the sea of that age over southern Hamilton county. Though mid-Ordovician strata are not exposed at or near Schroon Lake, such rocks may be there concealed, or they may formerly have been present. In any case, their strong development in the Champlain valley only 15 or 20 miles to the east renders it highly probable

[1] The early Paleozoic physiography of the southern Adirondacks is discussed by the writer in a paper in N. Y. State Mus. Bul. 164, p. 80–94. 1913.

that the mid-Ordovician sea spread far enough westward to cover at least the eastern part of the Schroon Lake quadrangle.

We have no positive evidence that any part of the Schroon Lake quadrangle has ever been submerged under sea water since mid-Ordovician time.

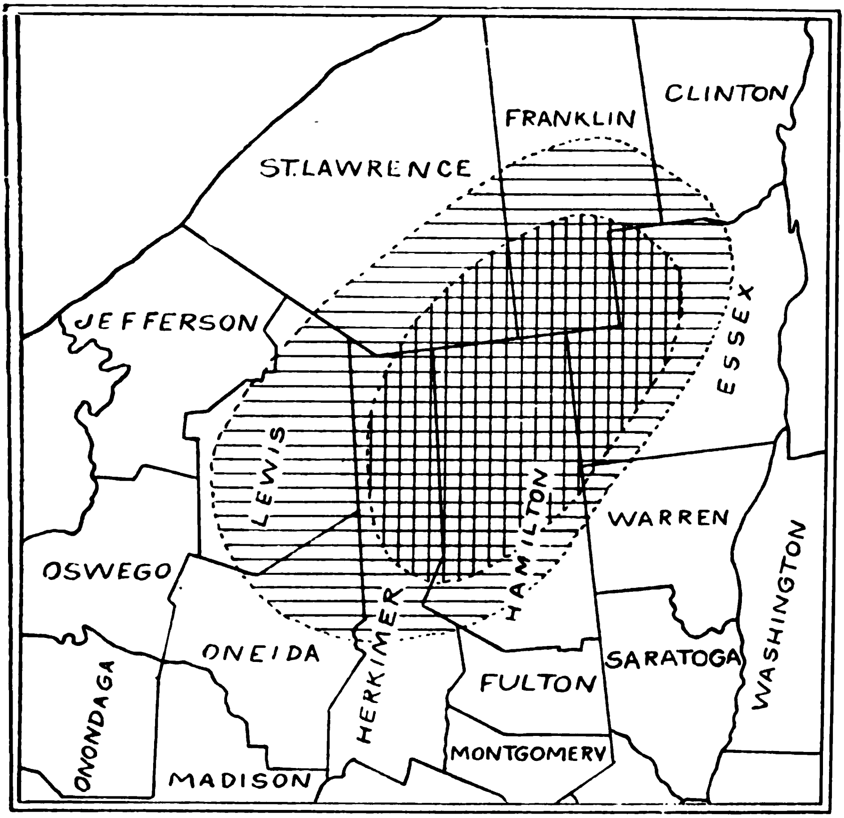


Fig. 6 Map of northern New York showing the general relations of land and water during parts of the Cambrian and Ordovician periods. The whole shaded portion represents land during the late Cambrian time, and the cross-lined portion represents land during the middle of the Ordovician.

STRUCTURAL GEOLOGY

Structure of the Grenville Series

Tilting and folding. Evidence has recently been presented by the writer[1] to show that the Grenville strata of the Adirondacks

[1] Jour. Geol., 24:588-96. 1916

have never been highly folded or severely compressed. Many broad belts of the strata are known to be practically horizontal or only very moderately folded, while many masses are merely tilted or domed at various angles. Very locally the strata exhibit contortions. The many scattering bodies of Grenville strata throughout the Adirondacks do not show any very persistent strike as would be the case had they been subjected to notable orogenic pressure.

The structural relations of the Adirondack Grenville strata are reasonably explained as having been the result of the slow, irregular upwelling of the great bodies of more or less plastic magmas, probably under very moderate compression, whereby the strata, previously deformed little or none at all, were either broken up, tilted, lifted or domed, or engulfed in the magmas. According to this view, many large blocks or belts of Grenville strata, or several such rather locally separated by intrusive masses, with strike of intrusive masses parallel to the strike of the Grenville, show monoclinical dips; many masses of Grenville were shifted around in the irregularly rising magmas to show various strikes and dips according to the direction of magmatic currents; some bodies of Grenville were merely domed over bodies of laccolithically rising magma and hence exhibit more or less quaquaversal strikes and dips; some masses of strata were considerably bent or even folded into synclines by being caught between bodies of magma upwelling at about the same rate; some masses, especially the more plastic limestones, were locally contorted near the igneous contacts; and many masses of strata were caught up or enveloped by the rising magmas.

The Grenville series within the Schroon Lake quadrangle is not extensively developed, and the exposures are mostly too scattering to throw much light upon its structure, but most of the types of occurrence above mentioned seem to be present, except probably the laccolithic. Strikes and dips are platted on the accompanying geologic map, though where several similar observations were made within one-fourth of a mile of each other but one is usually recorded.

In the Minerva area the Grenville strata seem to show a synclinal structure with a west-northwest strike of the axis through the village, but the outcrops are too scant to make this certain. If synclinal, it is not a very sharp fold because the dips generally vary from 30 to 50 degrees. A structure of this sort may be readily explained as due to greater upwelling of the granite magma on both the north and south sides of the mass of Grenville causing

the strata to be notably bent upward along those sides. It should be noted, in accordance with this view, that the strikes of the Grenville strata and the adjacent igneous rocks are essentially parallel.

In the northern portion of the Olmstedville area five good observations show the Grenville to have persistent dips of from 20 to 70 degrees northward, which is precisely the opposite of the Grenville of the northern portion of the nearby Minerva area, this latter being on the same strike. Such a sharp change would scarcely be expected as a result of ordinary orogenic folding, and it is more likely the result of the magmatic intrusion. The granite magma north of Olmstedville apparently broke through and flowed

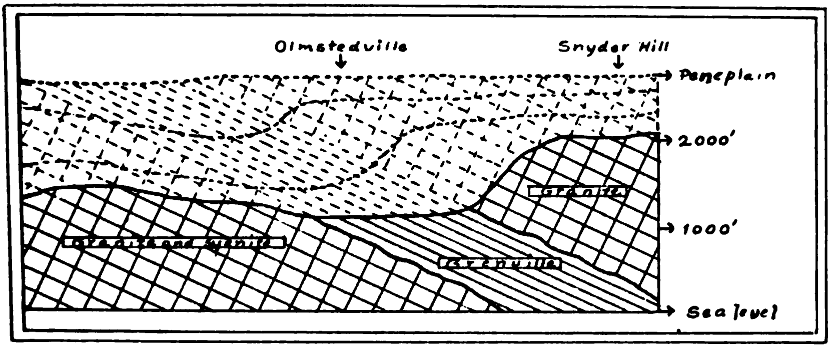


Fig. 7 An early north-south section through Olmstedville illustrating the geologic structure and the probable mode of origin of the valley in the vicinity of the village and the escarpment on the north. Several stages of erosion are shown from the late Mesozoic or early Cenozoic peneplain level (dotted upper line) to the present surface (heavy lower line). Length of section, 4 miles. Vertical scale, 2½ times the horizontal.

intrusively upon the Grenville strata, thus accounting for the northward dip of both granite and Grenville with the latter dipping under the former. Because of the much greater resistance of the granite to weathering and erosion, it stands out as a local scarp (see map), while the much weaker Grenville has been notably worn down to form the valley around Olmstedville. Figure 7 illustrates the principles here involved.

The very irregular dips and strikes in the small area of Grenville just east of North pond are no doubt due to deformation of this block of strata by one or more of the various intrusive masses which rose adjacent to, or possibly engulfed it. A similar condition is true of the Grenville south of Adirondack village.

The other mapped areas of Grenville are relatively small, and they are merely inclusions in the syenite-granite series. They

are usually lenslike or elliptical in ground plan and essentially parallel to the foliation of the inclosing rocks.

Figure 8 shows an interesting case of a sharply bent small mass of Grenville gneiss in granite on Ledge hill.

Foliation of the Intrusive Rocks

The anorthosite and syenite-granite series. The great instrusives of the quadrangle, including both the anorthosite and the syenite-granite series, exhibit more or less foliation, though large

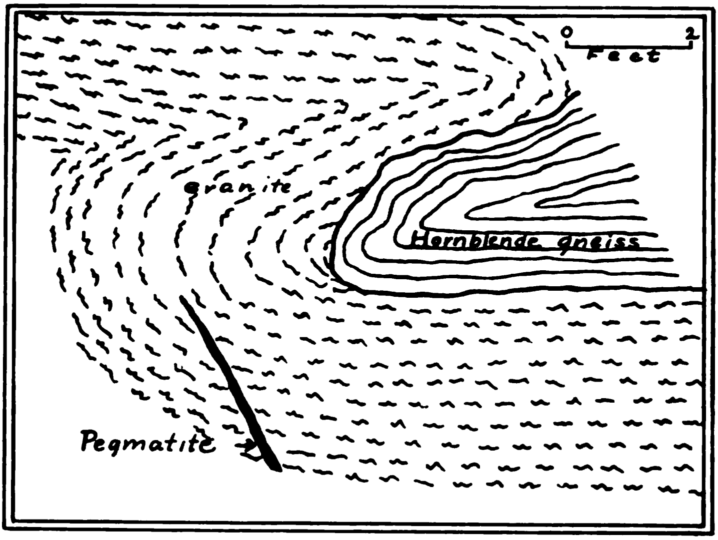


Fig. 8 Sketch showing ground plan of part of an exposure near the eastern border of the gabbro stock on Ledge hill. The gneissoid granite, with its sharply curving foliation, wraps about a portion of a sharply bent small inclusion of hornblende gneiss.

portions of the Marcy anorthosite commonly show practically none. In the syenite-granite series at least a faint foliation seldom fails to appear, and it varies from this to very highly foliated. The degree of foliation often varies notably within very short distances. Both strike and dip of the foliation also often vary notably, though the general trend or strike is from east-west to northwest-southeast. Regarding the foliation in the adjoining Paradox Lake quadrangle, Doctor Ogilvie says: "The general direction of strike is similar. A direction of N 40° E is the prevailing one, with low southeast dips." According to this, the general strike of foliation of the Schroon Lake quadrangle is almost at right angles to that of the Paradox Lake quadrangle. In many ledges the general strike

can be made out but not the dip, this being particularly true of the locally gneissoid portions of the Marcy anorthosite. The gneissoid structure is usually accentuated by the roughly parallel arrangement of dark minerals, though locally the granite, comparatively free from dark minerals, is strikingly gneissoid due to excessive flattening of feldspar and quartz.

Granulation of minerals, especially feldspar, is common in many localities and often highly developed, the more highly foliated rocks generally being most granulated.

On the accompanying geologic map there are recorded representative strikes and dips of foliation selected from many field observations.

The writer considers the foliated igneous rocks to be so-called "primary gneisses" whose gneissoid structure was developed as a sort of magmatic flow-structure under moderate compression rather than by severe lateral (orogenic) pressure brought to bear upon the region after the cooling of the magmas. Briefly stated, the writer's explanation follows.[1] During the processes of intrusion, which were long continued, the great magmatic masses were under only enough lateral pressure to control the general strike of the uprising magmas with consequent tendency toward parallel arrangement of instrusives and invaded Grenville strata; the foliation is essentially a flow-structure produced by magmatic currents under moderate pressure during the intrusions; the sharp variations of strike on large and small scales, and rapid variations in degree of foliation, are essentially the result of varying magmatic currents under differential pressure, principally during a late stage of magma consolidation; the almost universal but varied granulation of these rocks was produced mostly by movements in the partially solidified magma, and possibly to some extent by moderate pressure after complete solidification; and the mineral flattening or elongation was caused by crystallization under differential pressure in the cooling magma.

It would seem, therefore, that the general absence of foliation from so much of the Marcy anorthosite is best explained as the result of the much more uniform (laccolithic) intrusion of this single great body which is much less involved with Grenville masses, or, in other words, to much less forced differential flowage.

Figure 8 shows a case of sharp variations in strike within a few feet in the granite of Ledge hill.

[1] The writer has presented a rather full discussion of this subject in Jour. Geol., 24:600–16. 1916.

It is quite possible that much or all of the pressure within the intruding magmas was simply "shouldering pressure exerted (by the magmas) on the adjacent rocks under bathylithic, or deep-seated, conditions" as suggested by Cushing.

The gabbro and diabase. As already stated, the interior portions of most of the gabbro stocks are nonfoliated and they possess a diabasic texture, while the outer portions are usually highly foliated rocks, often true amphibolites. More or less granulation is common as seen in the thin sections. In many places the degree of foliation varies considerably within single stocks, a very fine example already having been described as occurring on the little hill just south of North pond (see page 58). The foliation shows a strong tendency to box the compass around the borders of the stocks, and, therefore, often strikes across the structures of the older adjacent rocks. If due essentially to regional compression after the solidification of the gabbro, should not the foliation everywhere strike at least approximately at right angles to the direction of application of the pressure? Also, how are the notable variations in foliation and granulation to be explained on the basis of regional pressure?

It is believed that the foliation and granulation of the gabbro stocks are largely, if not wholly, primary features due to movements in the magma before final consolidation. Considerable pressures must have obtained within the stock chambers while the magmas were being intruded under deep-seated conditions. Such pressure against the country rock, combined with the development of differential flowage particularly in the magmatic borders, would readily account for the peripheral foliated zones which were, no doubt, produced during a late stage of magma consolidation. But the conditions of magmatic pressure and flowage must have varied considerably, and thus the local variations in degree of foliation and granulation are accounted for.

Certain of the diabase dikes which cut the Marcy anorthosite in the vicinity of Blue Ridge village are also more or less foliated, their borders particularly so. As in the gabbro stocks, so here, the foliation is considered to have been due to differential magmatic flowage under moderate pressure during a late stage of magma consolidation. In these dikes, however, the foliation was developed parallel to the strike of the dikes because cross-sections of these magma chambers were long and narrow rather than rounded or elliptical as in the gabbro stocks.

Faults and Zones of Excessive Jointing

General features. The Schroon Lake quadrangle lies in the midst of the faulted eastern Adirondack region. Fifteen earth fractures are represented on the accompanying geologic map. More than likely there are others, but only those which show at least fairly satisfactory evidence for their existence are mapped. In most cases these earth fractures are rather well-defined faults, while in others they appear to be zones or belts of excessive jointing in which more or less crushing and minor faulting have taken place. These faults or broken-rock zones are relatively straight for considerable distances, ranging from a mile or two to 10 or 12 miles within the quadrangle. Where observations were made, the fault crush-zones are commonly from 25 to 100 feet wide. In accordance with most of the more conspicuous faults of the eastern Adirondacks, those of the Schroon Lake quadrangle mostly strike north-northeast. The topographic influence of the fault zones is usually very striking as a glance at the geologic map will reveal. It is very important to note that the fault zones of weakness, mostly clearly marked by long, narrow valleys, nearly all trend almost or quite at right angles to the strike of the foliation of all the rocks and to the general trend of the belts of relatively weak Grenville which are essentially parallel to the foliation (see map).

The faults are all of the normal type with fault surfaces vertical or very steep. Within the area of Precambrian rocks of the eastern Adirondacks it is often difficult to demonstrate the existence of faults and, when a given fault has been proved to exist, it is usually difficult or impossible to trace it across country with any great degree of accuracy because of scarcity of exposures due to accumulation of glacial and postglacial deposits in the fault valleys. Because of the character and structure of the rock masses (mostly igneous) and the lack of any very clearly defined stratigraphic relations, it is practically impossible to determine the actual amounts of displacements, though in some instances minimum figures can be given. Within the quadrangle such minimum figures are not definitely known to be more than some hundreds of feet, but actual displacements may have been many times as great.

Among the more positive criteria for the recognition of the faults and zones of excessive jointing in the quadrangle are the following: (1) long, narrow, almost straight valleys which trend at high angles across the strike of the older rock structures such as the foliation and the belts of Grenville strata; (2) steep to vertical

scarps, often miles long, in hard, homogeneous rock; (3) actual presence of crushed, sheared, slickensided or brecciated rock zones; and (4) Paleozoic strata lying at the base of steep hills of Precambrian rocks.

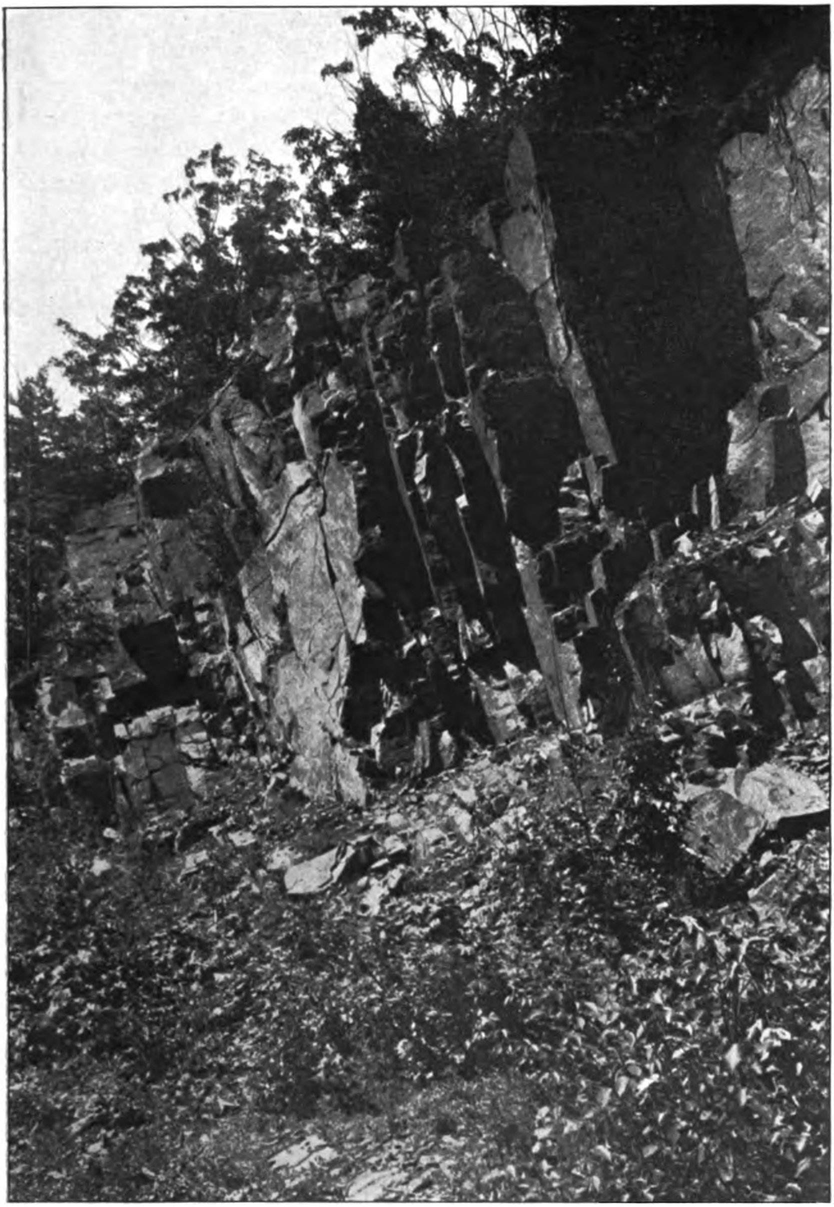
Age of the faulting. That some Adirondack faulting took place in Precambrian time has been pretty well established, but, so far as definitely known, such fractures are of minor importance. There is no positive evidence for such faulting in the Schroon Lake quadrangle. It seems quite likely as Cushing has suggested,[1] that considerable faulting took place during, or toward the close of, the Paleozoic era.

Any fault scarps, ridges or valleys which may have been produced by the close of the Paleozoic must have been nearly or quite obliterated by the long subsequent time of erosion. If so, how do we account for the present Adirondack ridges and valleys which follow the fault lines or zones? Accompanying the uplift of the late Mesozoic or early Cenozoic peneplain of the Atlantic coast region, or following it, there was either new faulting, or renewed movement along old faults, or old fault zones, including zones of excessive jointing with little displacement, were not affected by new movements. How much is new faulting, and how much renewed faulting along old lines or zones of fracture is not known, but it is quite certain that considerable faulting in the eastern Adirondacks must date from the uplift of the peneplain just mentioned as shown by fault scarps in homogeneous rocks and by the existence of tilted fault blocks which have been little modified by erosion. Some relatively long, deep, narrow, valleys of the Schroon Lake quadrangle, like that which follows the Minerva stream fault or the Hoffman notch fault (see below), are due essentially to erosion along the fault or broken-rock zones of weakness irrespective of when they originated, while others which are broader, like the Schroon Lake valley and the lowland between Green hill and Oliver hill, are due either to comparatively recent sinking of fault blocks, or removal of weaker rocks by erosion whereby old fault scarps are renewed, or both. Distinctly tilted fault blocks, like some in the North Creek quadrangle just to the south, are not certainly present in the Schroon Lake quadrangle.

Schroon valley fault. As represented on the geologic map, this is one of the two longest and most conspicuous faults of the quadrangle. Its scarp marks the western boundary of the Schroon

[1] N. Y. State Mus. Bul. 95, p. 405.

Plate 9



W. J. Miller, photo, 1917

The zone of excessive jointing accompanied by some faulting in the road metal quarry by the main road one-half mile east-northeast of South Schroon

valley for 12 miles across the quadrangle and beyond (northward) for fully 8 miles more. As regards both length and topographic influence, this fracture takes rank as one of the most prominent faults in the eastern Adirondacks. It probably does not extend south of the quadrangle limit. The topographic evidence for the fault is very strong (plate 3). The Potsdam sandstone east of Grove Point and the sandstone and dolomite in the valley 7 miles north of Schroon Lake village also both lie against the base of the scarp and hence furnish strong evidence for faulting with downthrow side on the east. Several ledges in the bed of Horseshoe pond brook are badly broken parallel to the course of the stream and these furnish still more positive evidence for the existence of the fault. Nowhere else along the immediate base of the scarp were outcrops of any kind observed, so that further evidence such as slickensides and crushed or brecciated zones, is lacking. From Thurman pond southward the trace of this fault is much less certain. Some idea of the minimum displacement along this fault may be gained not only from the height of the scarp but also from the positions of the outliers of Paleozoic strata. Thus the sandstone and dolomite 7 miles north of Schroon Lake village lie at an altitude of 900 feet, while the summit of the mountain just west is nearly 2300 feet, thus indicating a minimum downthrow of about 1300 feet on the east side of the fault. The position of the Potsdam sandstone west of Grove Point indicates a minimum displacement of at least 400 feet, and probably 600 feet.

Schroon lake faults. The topographic evidence for a fault, or at least a zone of excessive jointing, along the western side of Schroon lake is strong, as shown on the map. A very conspicuous zone of excessive jointing accompanied by moderate faulting (see plate 9) occurs in the road metal quarry one-half of a mile east-northeast of South Schroon. The strike of this jointed zone is parallel to the strike of the fracture as mapped but at a high angle to the strike of the foliation of the rocks. Probably the jointing exhibited in the quarry lies a little to the west of a real fault, because the topography strongly points to a downthrow of fully 200 feet on the east side.

From Adirondack village southward close to the lake shore there is a fault which is but the northern extension of a rather prominent fault several miles long which has been mapped and described in the writer's report on the North Creek quadrangle.

Along the eastern lake shore at the base of Quackenbush hill, and extending several miles into the Paradox Lake quadrangle, a

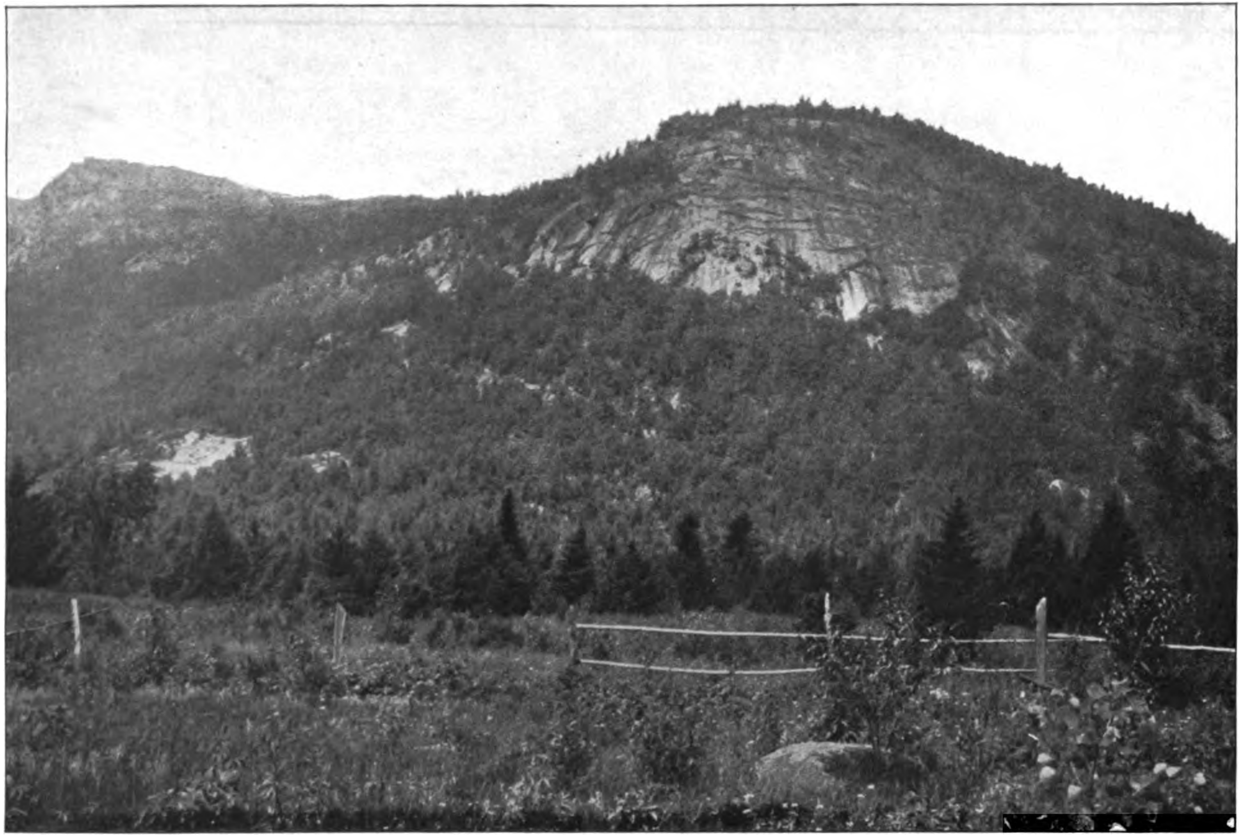
long, nearly straight line, with hills rising steeply hundreds of feet above it and at right angles to the old rock structures, makes the existence of a line or zone of fracturing there almost certain. This being the case, the outliers of Paleozoic strata in and near Schroon Lake village really lie in a "graben" or fault trough.

Fuller brook fault. This zone of fracture separates Pine hill and Ledge hill rather sharply and continues northward at least to Horseshoe pond. The topographic evidence is quite clear and, in the bed of the little brook about a mile south of Marsh pond, the rock is considerably broken as a result of earth movements. The topography suggests a moderate downthrow on the east, but instead of being a true fault this may be simply a zone of excessive jointing with little displacement.

Alder brook and Trout brook faults. That Alder brook and Trout brook follow fault zones for several miles as shown on the map is quite certain. Not only are these valleys narrow and remarkably straight, but they have been cut into granite at right angles to its structure. Such could scarcely be the case unless the positions of the valleys were determined by zones of weakness due to faulting. Further, the earth block between these two streams is very distinctly depressed below the country immediately on either side. The evidence, then, renders quite certain the existence of a fault block from 1½ to nearly 3 miles wide and several miles long which has sunk between two faults, one along Alder brook and the other along Trout brook. The topographic influence of this sunken fault block is particularly striking in its southern half where the Pine-Green hill mass on the east and the Oliver-Snyder hill mass on the west each rise hundreds of feet very abruptly. Direct evidence for the faulting from ledges along the fracture lines or zones is wholly wanting, not a single outcrop occurring on either of the brooks. The Alder brook fault continues for several miles south into the North Creek quadrangle (see North Creek geologic map).

Minerva stream fault. As regards both length and topographic influence, this fault takes rank as one of the most prominent known lines of fracture in the eastern Adirondacks. On the accompanying map it shows a length of 12½ miles. It continues southward for 6½ miles across the northwestern part of the North Creek quadrangle and thence for at least 3 miles into the Thirteenth Lake quadrangle. Its total length is, therefore, at least 22 miles. Its topographic influence is very striking since a deep, usually narrow, nearly straight valley has been cut out along this zone of weakness along its whole course of over 12 miles in the Schroon

Plate 10



W. J. Miller, photo, 1917

The steep mountain 1 mile southwest of Moxham pond as seen from a point one-half mile east of the base. The face of the mountain is 800 feet high and it lies on the upthrow side of the Minerva stream fault which passes along its base. This is a fine example of an exfoliation dome, many great slabs of the granitic syenite having peeled off due to changes of temperature

Lake quadrangle (plate 10). Southward, also, the topographic influence is pronounced. It seems quite clear that the downthrow side is on the east, this being most evident in the North Creek quadrangle where, just east of the Gore mountain mass, the displacement is at least 1500 feet. Within the Schroon Lake quadrangle the topography does not indicate so much displacement, though it is mostly at least some hundreds of feet except at the north where it is much less. In the Minerva stream valley no outcrops occur along the fault, but in the bed of the brook just west of Washburn ridge there are several exposures of rock badly broken by the faulting in zones parallel to the course of the stream. It is very important to note that the strike of this fault is almost exactly at right angles to the strike of the foliation of all the rocks, and also at right angles to the strike of the prominent belt of Grenville strata around Minerva and Olmstedville. It is difficult to conceive how such a long, narrow valley could have developed for 12 miles across these structures except along a fault zone of weakness in the rocks. The lowlands in the vicinity of Minerva and Olmstedville, and also in the vicinity of North Creek, are due to more rapid erosion of the comparatively weak Grenville strata in those localities.

Hoffman notch fault. Evidence for either a fault or zone of crushed or excessively jointed rock in the Hoffman notch valley is twofold. In the first place, the long, straight, deep, narrow valley, with north-northeast strike parallel to most of the prominent faults of the eastern Adirondacks and at right angles to the rock structures of the immediate region, almost certainly must have been carved out along a fault zone of weakness. This valley is 5½ miles long with a maximum depth of 1200 to 1500 feet. In the second place, actual crushed to even brecciated rock zones in the bottom of the valley and parallel to it were observed at a number of places, the principal ones being as follows: several ledges in the brook between one-half and 1½ miles north of the pond in Hoffman notch and several ledges in the brook between 1½ and 2 miles south of the same pond. The brook northeast of Hoffman notch pond follows a short branch fault for about one-half of a mile with much evidence of crushed rock. That the Hoffman notch fault continues northward across the east-west Blue Ridge-Boreas river road is proved by the existence of a ledge in the Branch brook just north of the road where closely spaced jointing with strike N 20° E is well shown.

Faults between Hayes mountain and Hewitt pond. West of Hayes mountain, Minerva stream flows through a narrow north-south valley which for 2½ miles has been carved out along a distinct fault zone of weakness. In the bed of the stream three-fourths of a mile north of the place marked "Camp" on the map, the granite is considerably broken due to the faulting. Along the stream one-third and three-fourths of a mile, respectively, south of "Camp," there are ledges distinctly broken or excessively jointed parallel to the stream channel. In one case a crushed-rock zone 10 to 15 feet wide is finely exhibited. The topography suggests moderate downthrow on the west.

A ledge in the bed of the stream one-half of a mile southeast of the mouth of Hewitt pond shows a distinct crush-zone with almost north-south strike, but with little or no topographic influence.

Hewitt pond brook also follows a fault zone of weakness with nearly east-west strike, this being the only definite fault in the quadrangle with such a strike. A few rods above the mouth of the brook in a small gorge the rock is considerably broken parallel to the channel.

Wolf pond brook fault. A narrow nearly straight valley 5½ miles long extends from Lester dam to north of Wolf pond. It has probably been developed along a zone of excessive jointing rather than along a distinct fault. In the bed of Wolf pond brook, one-third of a mile from its mouth, a big ledge is considerably broken by closely spaced joints parallel to the channel.

Boreas river fault. Boreas river, for 1½ miles after it enters the map area, quite certainly follows a channel which has been cut out along a fault zone or a zone of excessive jointing. One ledge along the stream shows the broken rock. This fault zone is really only the southern end of what is evidently a very prominent earth fracture extending far into the Mount Marcy quadrangle. The Ausable lakes are there located in this fault zone. The topographic influence in the Mount Marcy quadrangle is very striking.

Niagara brook fault. The long, deep, straight, narrow valley occupied in part by Niagara brook has quite certainly been determined by a fault or joint-zone of weakness. Counting its northern extension beyond the map area where its topographic influence is even more pronounced, this fault or joint-zone is 6 miles long. No broken-rock zone was observed within the Schroon Lake quadrangle, the bed of the brook there all being in glacial drift.

Other faults. A big ledge at the road corners southeast of Oliver pond is all cracked into small blocks. Also, ledges by the

road one-third of a mile west of Oliver pond show many closely spaced joints with nearly north-south strike. These zones of broken rock are apparently minor, and since they have no topographic influence they are not mapped.

The steep southern face of Moxham mountain strongly suggests a fault scarp, but it might have resulted by removal of Grenville strata, such rock now forming a considerable belt not far to the south.

In the bed of Boreas river 1 mile below Lester dam, the granite is much broken and badly weathered in a fault zone of weakness with nearly north-south strike, but there appears to be no topographic influence.

In still other places the topography suggests the presence of fault zones, but in no case has the evidence seemed strong enough to warrant mapping.

PLEISTOCENE GEOLOGY

General Statements

It is well known that, during the great Ice Age of the Quaternary period, all of New York State except portions of the extreme southern side was buried under a sheet of ice. That this great sheet of ice was thick enough to bury even the highest mountains of northern New York is proved by the presence of glacial pebbles and boulders at or close to many of their summits. This is true in the Schroon Lake quadrangle. In some cases striae and glaciated ledges have been observed several thousand feet above sea level, the highest which happened to be noted in the Schroon Lake quadrangle being at 2200 feet. Adirondack glacial lakes at altitudes of several thousand feet above sea level also bear strong testimony to great depth of ice. The general direction of movement of the ice across the Adirondacks was toward the south and southwest, with comparatively few local exceptions. Such a persistent direction of movement also strongly argues for complete burial of the region under ice. The ice spread southward as a part of the great Labradorean ice sheet of eastern Canada. When the ice, early in its southward movement, struck the Adirondack highland district, one portion flowed southward through the Champlain valley and sent a branch lobe westward into the Mohawk valley. At the same time another portion flowed around the western side of the mountains and sent a lobe eastward into the Mohawk valley. The two lobes, one from the east and the other from the west, met in the

Mohawk valley leaving the main portion of the Adirondacks free from ice. But, as the ice increased in volume, more and more of the Adirondack region was covered till finally even the highest points were buried. In a paper published by the writer some years ago, the movement of the great ice sheet across northern New York is discussed.[1] During the ice retreat the higher east-central Adirondack region was the first to be freed from the ice, and the ice-freed portion gradually increased in size.

Direction of Ice Movement

The direction of ice movement across the Schroon Lake quadrangle is clearly recorded by both glacial scratches (striae) and the distribution of glacial boulders. Distinct glacial striae were observed in twenty localities, their bearings and locations being plotted on the accompanying geologic map. They are as follows:

1 S 10° W. On Grenville gneiss 1¼ miles west-southwest of Schroon Lake village.

2 S 10° E. On granite by the road 1½ miles west-northwest of Schroon Lake village.

3 S 10° E. On diabase 1⅓ miles due west of Grove Point.

4 N-S. On granite three-fourths of a mile northeast of Charley hill.

5 N-S. On granitic syenite near the summit of Beech hill.

6 S 10° E. On granite by the road 1 mile west of Charley hill.

7 N-S. On granitic syenite by the road 1 mile northwest of Taylors on Schroon.

8, 9 S 10° E. Two records one-fifth of a mile apart on granite by the road three-fourths of a mile north-northeast of Pat pond.

10 S 10° E. On Grenville gneiss three-fourths of a mile due west of Minerva.

11 S 10° E. On granite by the road just south of Oliver pond.

12 N-S. On granite by the road one-third of a mile west-southwest of Oliver pond.

13 S 30° W. On granite by the road one-half of a mile west-southwest of Oliver pond.

14 S 10° E. On syenite by the road one-half of a mile northeast of Muller pond.

15 S 10° E. On Whiteface anorthosite by the road 1¾ miles west-northwest of Boreas river.

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[1] Amer. Jour. Sci., 27:289–98. 1909.

16 S 15° E. On Marcy anorthosite near the creek three-fourths of a mile northeast of Boreas river.

17, 18, 19, 20 S 10° E. Four records on Marcy anorthosite by the road between 1 and 1¾ miles east-northeast of Boreas river.

It will be seen from this list that the extreme range in direction of the glacial striae is from S 15° E to S 30° W. Further, all but two sets of the striae run from N-S to S 15° E. It is evident, therefore, that the general direction of movement of the ice over the quadrangle, except possibly its northeastern one-fourth where no striae were observed, was a little to the east of south. This harmonizes closely with the sixty sets of glacial striae observed by the writer[1] in the North Creek quadrangle next to the south, the average direction of which is almost exactly N-S.

Regarding the Paradox Lake quadrangle which lies just east, Doctor Ogilvie says:[2] "The more southerly and easterly parts of the quadrangle were in the region of the southwesterly moving ice current." Professor Kemp[3] has reached a similar conclusion regarding the southeastern portion of the Elizabethtown quadrangle, and further observations there by the writer reinforce this view. In the Blue Mountain quadrangle, the second to the west of the Schroon Lake quadrangle, the writer[4] has recently shown that the general direction of ice movement was southwestward. Professor Cushing[5] reached the same conclusion regarding the Long Lake quadrangle. As shown by the writer,[6] the general ice current was southwestward across the Lake Pleasant quadrangle in the south-central Adirondacks.

From the above facts it is evident that the southward to even slightly southeastward movement of the ice across the Schroon Lake and North Creek quadrangles was rather strikingly exceptional, having been surrounded by the great sheet of generally southwestward moving ice. The writer has no explanation for this puzzling fact. Local topographic control of the ice current in the Schroon Lake area can not have been the cause of the deflection because most of the prominent ridges and valleys have a north-northeasterly strike and the others vary from east-west to north-west, so that the ice moved across these sets of valleys at angles of from 20 to 90 degrees. The location and strike of striae in valleys,

[1] N. Y. State Mus. Bul. 170, p. 66. 1914.
[2] N. Y. State Mus. Bul. 96, p. 470. 1905.
[3] N. Y. State Mus. Bul. 138, p. 95. 1910.
[4] N. Y. State Mus. Bul. 192, p. 48. 1916.
[5] N. Y. State Mus. Bul. 115, p. 495. 1907.
[6] N. Y. State Mus. Bul. 182, p. 63–64. 1916.

like those north of Pat pond and east of Boreas river or at the summit of Beech hill, clearly prove the failure of the topography to determine the direction of the ice movement.

Ice Erosion

There is no evidence that the ice was a vigorous agent of erosion within the quadrangle. It may possibly have scoured out and somewhat deepened the basin of Schroon lake, but definite proof is lacking. Certainly none of the more prominent valleys were produced by ice erosion, for, as above shown, the main body of the ice flowed across the trend of the valleys rather than parallel to them as would have been necessary for ice erosion to have been very effective for their development or even notable modification.

It is quite certain, however, that the ice did remove from its original position practically all the preglacial soils and most of the rotten rock. Further, the vast number of glacial pebbles and boulders of comparatively fresh rocks clearly show that much relatively fresh rock must have been removed probably by the process of plucking or pushing off joint blocks which during transportation became more or less rounded. Altogether, however, the total amount of material eroded by the ice made no marked difference in the preglacial topography. The dumping of glacial material in the valleys during and after the ice retreat has probably altered the topography more than erosion by the ice.

Glacial Deposits

Morainic deposits. Typical morainic deposits, mostly glacial till or ground morainic material, are common throughout the quadrangle though usually they are more or less associated with stratified or fluvio-glacial materials. Boulder clay is seldom seen. Morainic deposits are particularly well developed over the lower lands or valleys, while well up on the hills and mountains they are usually absent or thin. It is evident that, during the retreat of the great ice sheet, the burden of morainic material was largely dumped in the valleys either by direct deposition from the ice or by water in connection with the ice, or both.

The most extensive development of morainic and fluvio-glacial deposits is in the area of over 6 square miles mapped as Pleistocene in the central portion of the quadrangle. Within this area the hard rocks are everywhere concealed under glacial deposits

Plate 11

W. J. Miller, photo, 1916

A great glacial boulder of Marcy anorthosite near the southeastern base of Cobble hill three-fourths of a mile southwest of Warren's Hotel. It is approximately 33 feet long, 27 feet wide, and 25 feet high. It was carried at least a few miles from its parent ledge by the ice during the Ice Age. Due to weathering and freezing of water along a joint crack, the boulder has been split open since it was left by the ice.

except at the four places indicated on the map. A little west of the middle of this area, there is an area of nearly a square mile, mostly an old clearing, where a boulder moraine is conspicuously shown.

In the area of Pleistocene east and southeast of Olmstedville morainic and fluvio-glacial deposits are also well exhibited, with boulders especially prominent in the northern half. In and near Olmstedville, in the area of Grenville, there are also fine developments of morainic and fluvio-glacial materials with boulders common.

Very conspicuous boulder morainic deposits occur for a mile on either side of the Trout Brook valley from 1 to 1½ miles southeast of Muller pond.

The Pleistocene of the area between South Schroon and Grove Point is largely morainic material.

Among many smaller scale morainic deposits are those in the valley east of Catamount hill, and three-fourths of a mile southwest of Irishtown.

Glacial boulders (erratics). Glacial boulders or erratics are very abundant and widespread over the quadrangle, though they are much less common on the tops of mountains and hills than over the lowlands. Some of the more prominent groupings of boulders in so-called "boulder moraines" are mentioned above. In addition to those there should be noted the accumulation of hundreds of large and small angular masses of Potsdam sandstone just southwest of Thurman pond and all over the area of Potsdam sandstone north of the pond.

An 8-inch angular fragment of typical Trenton limestone was noted a few rods west of the south end of Thurman pond. This suggests either a hidden ledge of such rock in this portion of the Schroon valley, or a mass scraped off and broken up by the ice, though the fragment might possibly have been carried by the ice for many miles.

While numerous boulders represent various types of the region, most of the largest ones are of Marcy anorthosite. The writer was particularly impressed by many boulders, usually only moderately rounded, ranging from 10 to 20 feet in diameter in the woods on the southern portion of Texas ridge.

A very large and interesting glacial boulder of Marcy anorthosite lies in an old field near the southeastern base of Cobble hill three-fourths of a mile southwest of Warren's hotel. Roughly meas-

ured, it is 33 feet long, 27 feet wide and 25 feet high. Since its deposition by the ice it has been split open along a joint surface. Plate 11 shows the appearance of this boulder. It was transported at least several miles, since the nearest outcrops of Marcy anorthosite are that far to the north.

Two remarkable boulders of Marcy anorthosite are shown in plate 12. They are close to the road two-thirds of a mile south of Wolf pond. Both are notably rounded, suggesting transportation for a number of miles at least. One of them, at least 14 feet in diameter, rests in a remarkably balanced position upon the other large one which is partially buried in the glacial drift. It scarcely seems possible that the upper boulder can retain such a position, and yet it remains there in spite of an attempt some years ago to pry it off.

Kames and eskers. Kames and eskers definitely recognizable as such are not common in the quadrangle. In the areas of heavy glacial and fluvio-glacial deposits, some of the little hills strongly suggest their origin as kames, but, since their structure is rarely ever revealed, this is not certain.

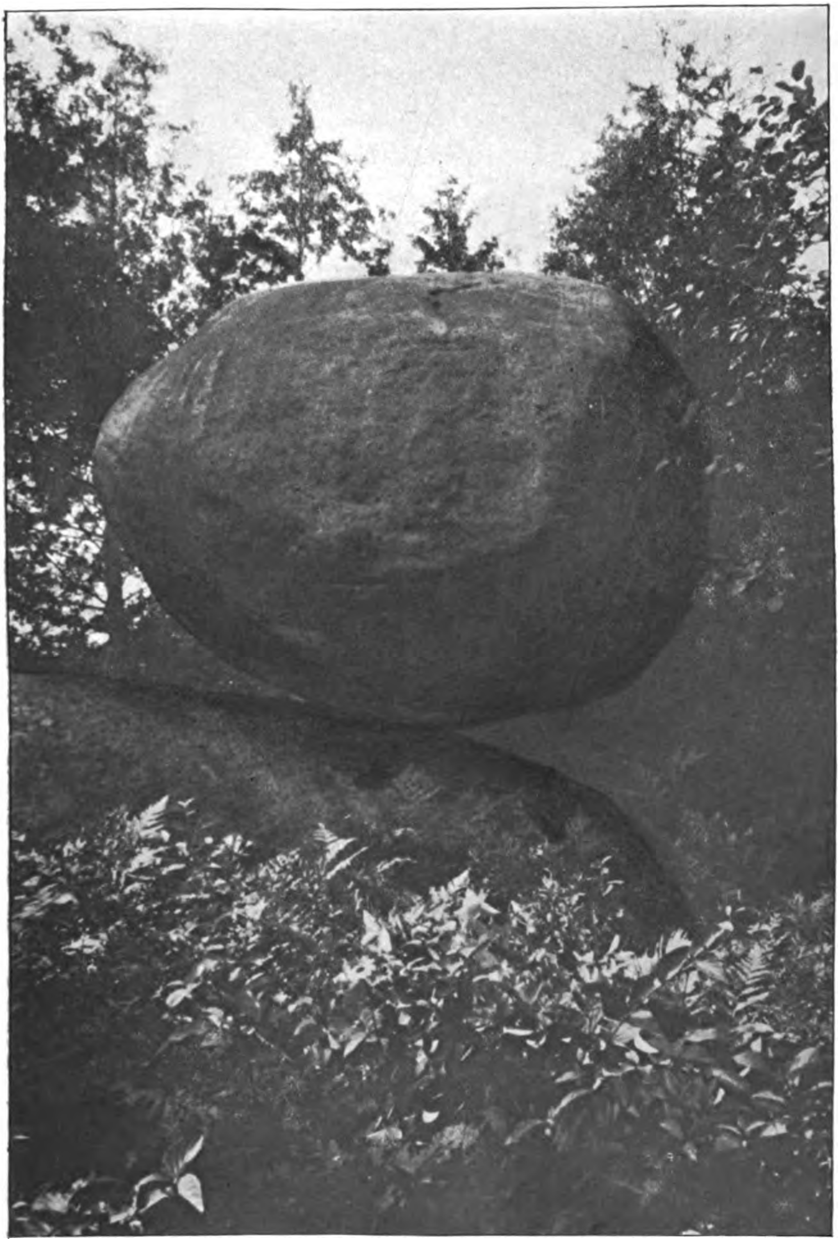
But one clearly defined esker was observed, and this is a very fine one. It lies just northwest of Schroon Lake village with a sinuous course and a general north-south strike for more than two-thirds of a mile. Its northern end comes against the base of the steep hill. The contour map only roughly suggests its position. It consists of sand and well-rounded small to large pebbles. In height it varies from 20 to 75 feet. Toward the north where it is highest and covered with trees, it is a very steep-sided narrow ridge. Plate 13 shows part of it toward the south in an open field where it is neither so high nor so sharply defined. This esker was probably formed by a debris-laden stream from the hillside upon or under the ice of the great waning ice sheet which still lay in the valley.

Lakes and Their Deposits

Extinct lakes. *Glacial Lake Pottersville.* This former large lake was first recognized by the writer and described in his report on the North Creek quadrangle.[1] It is named from the village of Pottersville which lies on the old lake bottom. Its waters spread through the Schroon valley from near Chestertown, over the site of Schroon lake, and to north of North Hudson. Branches of the

[1] N. Y. State Mus. Bul. 170, p. 70-72. 1914.

Plate 12



W. J. Miller, photo, 1917

A rounded glacial boulder of Marcy anorthosite fully 14 feet in diameter resting in a remarkably balanced position upon another boulder of the same kind of rock by the Blue Ridge-Boreas River road two-thirds of a mile south of Wolf pond

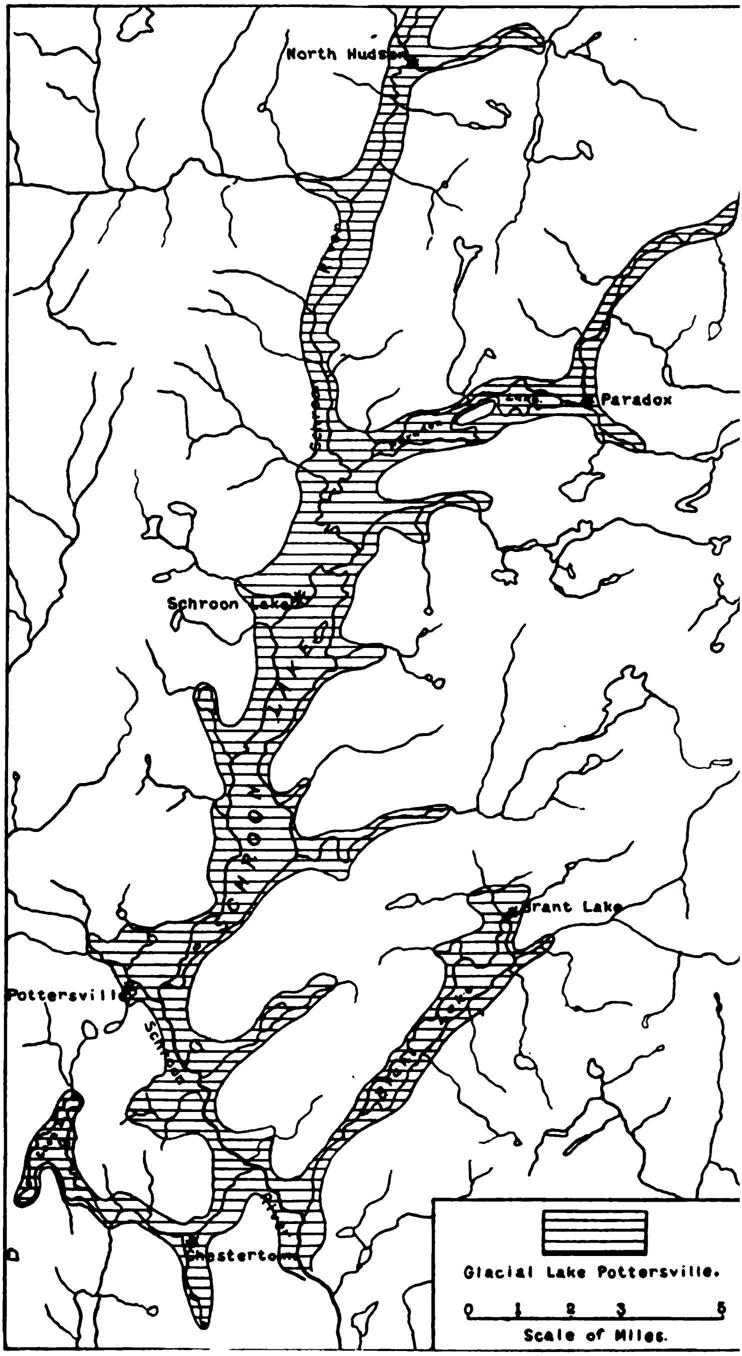


Fig. 9 Map showing the general extent of glacial Lake Pottersville.

lake spread out over the sites of the present Paradox, Brant and Loon lakes. Figure 9 shows the general extent of the waters of this great lake.

Glacial Lake Pottersville came into existence after the retreat of the ice because of a dam, probably morainic, across the Schroon valley east of Chestertown.

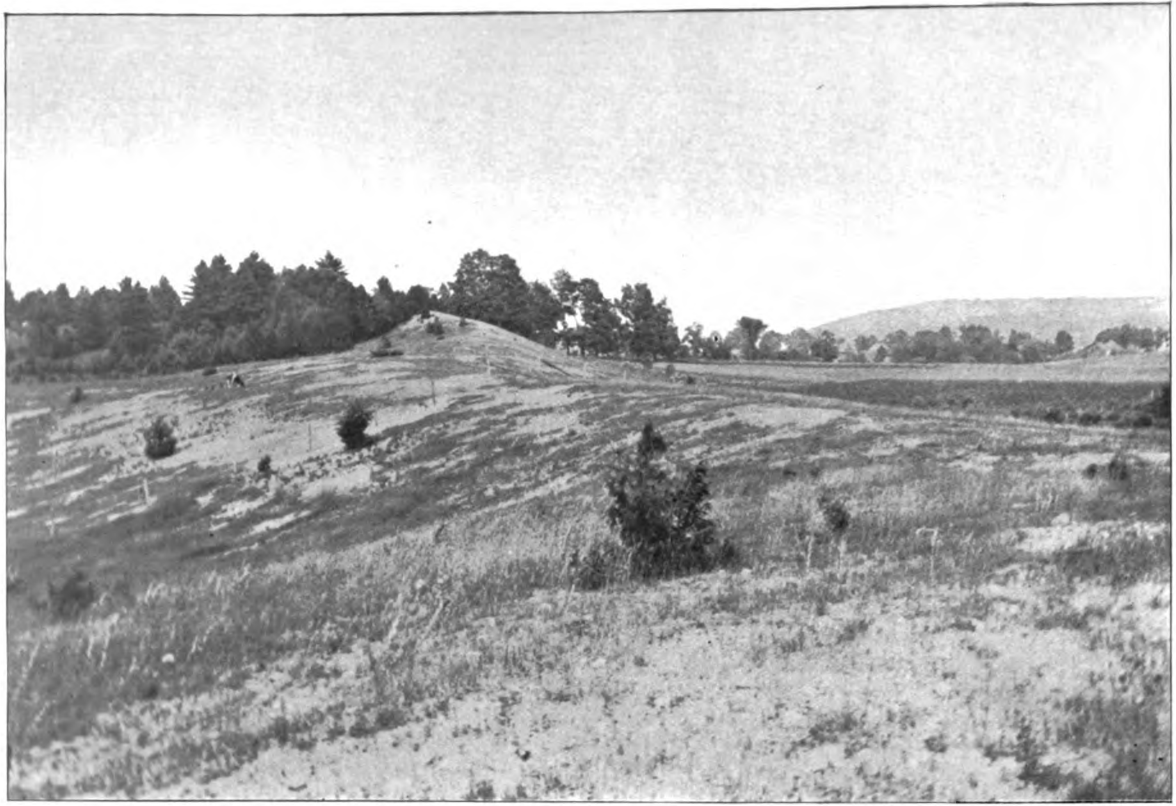
The former existence of this large body of water is demonstrated by the presence of numerous almost perfectly preserved very typical delta sand flats or plains at nearly accordant levels. Such deposits must have formed in standing water. In the vicinity of Pottersville the highest water-laid lake deposits are a little below the 900-foot contour; near Schroon Lake village they are at about 920 feet, and at North Hudson about 960 feet. In the Schroon valley of the Paradox Lake quadrangle there is an almost continuous succession of finely developed sand flats or terraces. The northward increase in altitude of these high level lake deposits is due to postglacial differential uplift of the land with a northward increase at the rate of several feet a mile. This harmonizes with similar findings regarding postglacial changes of level in the Champlain valley.

A fine section exhibiting the structure of the delta material occurs along the state road just west of Schroon Lake village. The delta terrace is well displayed for 2 miles northward from the village, several kettle-holes occurring on it, these having probably resulted from the melting of stranded icebergs which had been surrounded by, or possibly buried under, the delta sands. The steep eastern front of this terrace, so clearly shown on the contour map for 2 miles northward from the village, is the result of erosion by the meandering Schroon river.

Glacial Lake Pottersville was destroyed as such by cutting down its outlet east of Chestertown. Schroon lake is but a remnant of the former great lake.

Glacial Lake Minerva. This former lake is so named because it lay in the valley of Minerva stream in the town of Minerva. Moxham pond is a tiny remnant of this body of water which was fully 6 miles long. The area of the lake was almost exactly the same as that of the area of Pleistocene represented on the geologic map. A morainic dam at Olmstedville was quite certainly the cause of the ponding of this water. At the village, Minerva stream has cut a deep channel through this morainic deposit, and thus the lake has been drained. The water level stood at what is now the

Plate 13



W. J. Miller, photo, 1917

A view of part of the southern end of the esker just northwest of Schroon Lake village. Looking north from the top of the esker

1180-foot contour level toward the south end, and the 1200-foot contour toward the north end. Fine displays of delta sand flats occur in the vicinity of Irishtown, and along the lower road between Irishtown and Olmstedville. Along the old road near the northern end of the lake bed there is a long delta terrace of mostly fine to coarse gravel, such coarse material being due to the fact that Minerva stream there emptied into the lake and dumped its load of coarse debris. The old lake deposits have been considerably cut away throughout the valley by the meanderings of Minerva stream.

Glacial Lake Blue Ridge. The bottom of the valley of the Branch west of Blue Ridge village is remarkably flat and free from boulders. It is certainly the bed of a former lake. The 1200-foot contour closely follows the old shore line of this body of water which was fully 3 miles long and one-fourth to two-thirds of a mile wide. Its water was held up by a barrier of either ice or morainic material (probably the latter) in the vicinity of Blue Ridge village. In the vicinity of the village the limits of the lake are not very clear, but otherwise the area of the lake was approximately that of the area of Pleistocene shown on the geologic map.

Other extinct lakes. All the flat areas of swamp lands indicated on the map are beds of former ponds and small lakes, the more conspicuous ones being along Ryan, Alder, Trout and Wolf pond brooks, and from 1 to 2 miles southeast of Lester dam. In these cases the pond or lake basins have been completely filled with sediments and vegetable accumulations. Among the cases where the lake-filling process has been only partially completed are the basins of Bailey, Muller, Rogers, Marsh, Thurman, Hoffman notch, and Wolf ponds. The swamp areas around these ponds represent the amount of pond filling which has taken place since the Ice Age.

Existing lakes. Of the thirty or more lakes and ponds of the quadrangle, all except a few with artificial dams have their waters held up by dams of glacial drift. Largest of all is Schroon lake, 7 miles of whose 9 miles in length lie within the quadrangle. As already pointed out, it is but a remnant of former glacial Lake Pottersville. It may be regarded as merely a local enlargement of Schroon river whose waters are held back by Pleistocene deposits in the vicinity of Pottersville. It is possible that the Schroon lake basin was somewhat deepened by ice erosion during the great Ice Age, but data regarding this point are not in the possession of the writer.

Cheney pond was a small natural pond in the northern part of the basin now occupied by the large body of water of the same name, the building of Lester dam having raised the water to the present level.

Brace dam no longer holds back the water of Boreas river as shown on the map.

Hewitt pond occupies a rather delicately balanced position as regards its outlet. A trench, perhaps not more than 10 feet deep, cut through the narrow barrier of loose glacial drift along its southwestern side would allow the pond to drain westward into the Boreas and Hudson rivers, instead of eastward as now into the Schroon river.

The other ponds of this region require no special description.

Postglacial Changes of Level

It is a well-known fact that, during the closing stages of the Ice Age and just afterward, northern New York, including the area of the Schroon Lake quadrangle, was submerged hundreds of feet below the present altitude, and that tide water extended through the Champlain valley. This is proved by the presence of marine beaches with fossils several hundred feet above sea level in the Champlain valley. The most recent earth movement in northern New York has been that which has brought the marine deposits to their present position above sea level. This earth movement has been differential with greatest uplift toward the north, the rate of increase northward having been several feet a mile. The differential uplift appears to be clearly recorded within the Schroon Lake and adjoining Paradox Lake and North Creek quadrangles where, as already shown, the delta terraces and sand plains of former glacial Lake Pottersville gradually increase in altitude northward at the rate of several feet a mile. The deposits in glacial Lake Minerva also seem to show a similar uplift, but the evidence there is not so decisive.

Plate 14

Looking south through the narrows of Schroon lake from the village

SUMMARY OF GEOLOGICAL HISTORY[1]

Prepaleozoic History

The Grenville series comprise the oldest known rocks of the quadrangle. They are metamorphosed sediments usually with their stratification more or less well preserved. They are thought to be of Archeozoic age; that is, they belong among the oldest known rocks of the earth. Since Grenville strata are widespread in northern New York and much of eastern Ontario, it is probable that they were deposited under sea water, and, since they are at least some miles thick, the time required for their deposition must have been no less than a few millions of years. In the Adirondacks the Grenville strata were probably subjected to static metamorphism whereby the original shales, sandstones and limestones were completely crystallized into various gneisses and schists, quartzite and crystalline limestone (marble). The Grenville strata show a very irregular or "patchy" distribution because they have been badly cut to pieces by great bodies of intrusive rocks. Because of the breaking up of the strata into masses great and small by the intrusives, they are in many places highly tilted or moderately bent, and in some places locally contorted, but there is no evidence that they were ever notably folded by orogenic pressure. In fact the combination of well-preserved stratification of the thoroughly crystallized sediments and foliation due to flattening of minerals always parallel to the stratification would scarcely be expected if severe lateral compression of the strata had ever taken place.

The oldest known intrusive is the anorthosite which worked its way up into the crust of the earth as a relatively stiff gabbroid magma, probably laccolithically. From the gabbroid magma the anorthosite differentiated. The rising magma for most part lifted or domed the Grenville strata over it, but also to some extent its borders engulfed fragments of the strata.

Distinctly later, though apparently not very much (geologically) later, came the intrusion of a tremendous body of magma now represented by the syenite-granite series. This vast magma for most part slowly and very irregularly worked its way upward, and

[1] The interested reader who may not be very familiar with the science of geology might care to consult a recent work by the writer entitled *The Adirondack Mountains*, which is a somewhat untechnical guide to the geology and physiographic history of the Adirondack region. This is published as New York State Museum Bulletin 193.

in places actually domed the Grenville over itself. Mostly, however, this magma either broke up or tilted masses of Grenville great and small, or broke through it as great off-shoots from the magma, or even more intimately intruded or injected it. The more or less well-developed foliation of both the anorthosite and syenite-granite is regarded as essentially a magmatic flow-structure produced under the pressure conditions of the intrusions.

At some time after the deposition of the Grenville strata, the whole Adirondack region was elevated well above sea level. Whether this uplift took place prior to the great igneous activity, or during the instrusion of the anorthosite or syenite-granite, or both, is not definitely known, but it is reasonable to think that the same great force which caused the updwelling of one or both these magmas also produced the general uplift of the region.

Just when the metamorphism of the Greenville strata took place is not known, but there is strong evidence that it took place either before or during the great igneous activity and not afterward.

Following the intrusion of the syenite-granite series, there was a time of minor igneous activity when the gabbro magma was forced upward into the earth's crust mostly in the form of stocks sharply cutting the older rocks. Intrusions of pegmatite and aplite dikes also took place, some after the gabbro, and some probably before it.

The general elevation of the region above referred to inaugurated a time of profound erosion which lasted at least some millions of years, even well into the Cambrian period of the Paleozoic era. This is proved by the fact that all the rocks above mentioned are now at the surface and exhibit textures and structures which could have been produced only under deep-seated geologic conditions, that is many thousands of feet below the surface of the earth.

After the removal, by erosion, of a great thickness of rock material, the last Prepaleozoic igneous activity of the region took place when the molten diabase was forced into narrow fissures in the earth and cooled in the form of dikes. This diabase is known to cut all the other rocks. That it must have cooled rather near the earth's surface is evidenced by the usually fine-grained to even glassy texture.

Paleozoic History

As a result of the vast erosion above mentioned, the whole Adirondack area was worn down to near sea level and it presented at most only a very moderate relief. Then, in late Cambrian time,

a gradual submergence took place which allowed the sea to encroach well upon the old land surface. As shown by the outliers at and near Schroon Lake and elsewhere in the eastern and southern Adirondacks, the first sediment to deposit on the floor of the encroaching sea was the Potsdam sandstone, followed in turn by the Theresa sandstone and dolomite and the Little Falls dolomite, all of late Cambrian age. That the eastern and southern sides of the Schroon Lake quadrangle were submerged under the late Cambrian sea is proved by the existence of the outliers of rocks of that age in the Schroon valley and near North River close to the southwestern corner of the quadrangle. There is no evidence that the late Cambrian sea covered the northwestern portion of the quadrangle (see figure 6).

Within the quadrangle, positive data regarding the Ordovician history are wholly lacking. It is however known that all of northern New York was moderately above sea level toward the close of the Cambrian, and that submergence again occurred during the Ordovician so that, toward the middle of that period, all but probably a large low island in the east-central Adirondack region was under sea water (see figure 6). It is highly probable that, during part of the period at least, the Ordovician sea spread over part of the Schroon Lake quadrangle.

There is no reason to believe that marine waters ever spread over any more than the fringe of the Adirondack area at any time since the Ordovician. In other words, the Adirondack district has been a land area subjected to erosion ever since Ordovician time.

Mesozoic and Cenozoic History

As a result of the long time of erosion from the Ordovician period to late in the Mesozoic era or early in the Cenozoic era, most of northern New York was reduced to the condition of a fairly good peneplain with some masses of relatively hard rocks, especially in the east-central Adirondacks, rising to moderate heights above the general level.

Then the great peneplain (commonly called the "Cretaceous peneplain") was upraised and a new period of active erosion was inaugurated which has continued to the present day. There is some reason to think that this erosion proceeded far enough to permit the larger rivers, like the Schroon, to reach an almost graded condition, after which there was moderate renewed uplift.

Much of the faulting of the eastern and southern Adirondacks dates from the time of this peneplain uplift or even later, though it is likely that some took place much earlier.

Immediately preceding and probably during much of the great Ice Age, this region, like all the northeastern United States, was considerably higher than now, as proved by such drowned river channels as the lower Hudson and St Lawrence.

During the Ice Age of the Quaternary period, the area of the quadrangle, in common with nearly all of New York State, was buried under the great ice sheet which has left many records, such as striae on the ledges, glacial boulders, moraines and glacial deposits in general. The preglacial topography was not profoundly affected by ice erosion and deposition. The many extinct and existing lakes of the quadrangle were formed either by actual presence of the ice dam itself or, more commonly, by irregular deposits of drift across old stream channels.

A subsidence of the land several hundred feet below the present level took place toward the closing stages of the Ice Age or immediately after for this latitude, when arms of the sea extended through the Champlain and St Lawrence valleys. The area of the Schroon Lake quadrangle was then, of course, lower than now.

The most recent movement of the land has been a differential uplift with greater elevation toward the north. At the latitude of the Schroon Lake quadrangle, this postglacial uplift has amounted to several hundred feet with greater uplift toward the north, the rate of increase in elevation northward having been several feet a mile. The differential character of this uplift is well shown by the delta deposits of the extinct glacial Lake Pottersville.

MINES AND QUARRIES

Graphite

A graphite mine is located at the western base of Catamount hill about 10 or 15 rods northeast of the confluence of Trout and Alder brooks. The mine has not been in operation for several years, but the buildings still stand, and a considerable quantity of the graphite-bearing rock is piled up.

The mine workings are located on a belt of Grenville biotite-graphite schist some 30 or 40 feet wide. Most of the rock of this belt is in very thin layers and contains tiny flakes of graphite, but one zone in it, a few feet wide, is extra rich in large thin flakes

of graphite, many of which range from 1 to 5 millimeters across. This extra rich layer was the one principally worked. A band of crystalline limestone a few feet thick, containing graphite and green pyroxene, lies in contact with the graphite schist. The strike of the rock is N 50° W and the dip S 60°. Some small workings are at the surface, but the main operation was running a shaft said to be 75 feet deep and now filled with water.

Graphite flakes commonly occur scattered through the crystalline limestone of the Grenville areas around Minerva and Olmstedville, but not in such form or quantity as to be commercial at present.

Garnet

On the hill one-third of a mile southwest of Calahan pond, there are two places close together where red garnet was mined to some extent a good many years ago. In the smaller mine opening, which lies just west of the map boundary, the garnet, in irregular to rounded highly fractured masses up to several inches in diameter, is associated with Grenville coarse crystalline limestone and considerable green pyroxene in crude crystals up to an inch in length. This Grenville is twisted into gneissoid granite, the relationship being very clear. Some much smaller inclusions of pyroxene and garnet rock are sharply defined in the granite. The larger opening, whose location is indicated on the map, is 50 feet long and 30 feet wide. It shows similar rocks except that no granite actually appears in the mine opening. Granite does, however, outcrop only a few rods away. It is probable that these garnets developed during the process of metamorphism along and close to the contact between the Grenville strata and the granite.

Garnets occur in various other rocks of the quadrangle, being especially abundant in certain of the Grenville hornblende-garnet gneisses, and in certain facies of the anorthosite and syenite-granite series, but in all these the garnets are generally too small and scattering to be of commercial value.

Iron Ore

Minerva mine. This small mine is situated 2¼ miles due north of Minerva village or three-fifths of a mile southeast of Sherman pond and at an altitude of 1900 feet (see map). The Burden Iron Company conducted the last mining operations in 1881 and sent the ore to Troy.

In a description of this mine Newland[1] says: "The deposit has a northwesterly strike in conformity to the general trend of the country rocks. It has a flat dip of not more than 10° northeast, but as the surface rises sharply in that direction, the overburden soon becomes too heavy for open-cut work. There are a number of pits and trenches along the outcrop, extending altogether for a distance of 100 rods. A breast of ore 12 or 15 feet thick is exposed in the middle section. The thickness diminishes toward the ends, but it was not possible to estimate the size with accuracy owing to the partial filling in of the pits. Some drilling is said to have been done a number of years ago to test the ore body in depth; the records, however, have not been available for use in this report."

"The ore is a fairly coarse, granular magnetite. Samples taken from different parts of the body indicate an iron content above 50 per cent on the average, so that it would be classed as of rich grade. The principal impurity is pyrite which seems to be concentrated in narrow bands and is not generally admixed with the magnetite. A quantity of the more sulfurous ore has been left on the surface near the openings."

As far as could be determined in the old pits, now considerably filled with water, the ore appears to be a crude, lenslike mass directly associated with an intimate mixture of granite and older dark gneisses. The granite is gray to pinkish gray with well-developed foliation, being locally almost schistose. The older rocks are chiefly hornblende and hornblende-biotite gneisses with some garnet and pyrite, and dark green pyroxene gneiss. In this connection it may be noted that similar ore has been described by the writer as occurring in like association with closely involved syenite or granite and dark gneisses in both the Port Leyden and Remsen quadrangles, and by Cushing in the Little Falls quadrangle, all of these along the southwestern border of the Adirondacks. It would seem that when the syenite or granite magma worked its way through or alongside the dark gneisses, the conditions were somehow favorable for the segregation of the magnetite.

Prospect near Loch Muller. In and about a small prospect opening three-fourths of a mile northwest of Loch Muller, magnetic iron ore also occurs in direct association with intimately mixed

[1] N. Y. State Mus. Bul. 119, p. 89–90. 1908.

granite and hornblende gneiss. Hornblende gneiss is all shot through by pink granite, and the magnetite occurs as small, irregular masses through the mixture.

Road Materials

So-called "trap rock" is typically represented by the diabase dikes of the quadrangle. Such rock ranks among the very finest of all natural road-building material because of its hardness, fineness of grain, homogeneity, freedom from mica, and good binding power, this last being due to richness in iron-bearing minerals. None of the diabase dikes of the quadrangle has ever been worked though two of them, northwest and southwest of Schroon Lake village (see map), are large and well located for quarrying purposes.

The gabbro stocks, especially those free from mica, would furnish a large amount of hard, homogeneous road material with good binding power. None of these stocks has been quarried, though some of them are very favorably situated with reference to prominent highways.

Rocks of the syenite-granite series, particularly those portions free from mica, also yield a good quality of road material where an artificial binder such as tar is used. There is practically no limit to the available quantity of such rocks, though only two quarries for road material have been opened in them. One of these (with a smaller one close by) is in syenite by the state road one-half of a mile east-northeast of South Schroon, and the other is in granite near the state road one-half of a mile north of Moxham pond.

The quarry in the Little Falls (?) dolomite in Schroon Lake village has been operated for road material.

In several places small quarries or pits are located in disintegrated, coarse, crystalline Grenville limestone. This material, which is gravelly and readily dug out, is used for local road repairing. Among such small quarries are those near the road one-half of a mile southwest of Olmstedville, and 1 mile northwest of Olmstedville.

Building Stone

Building stones of fine quality occur in practically inexhaustible amounts within the quadrangle. The members of both the anorthosite and syenite-granite series would rank as very strong, durable, often beautiful building stones. In a few places very small

quantities have been quarried for local purposes, but none has been quarried for shipment.

An interesting old quarry in Grenville crystalline limestone is situated 1½ miles northwest of the summit of Hayes mountain and one-fourth of a mile west of Minerva stream (see map). The rock is a greenish, more or less mottled, medium-grained, crystalline limestone of the sort usually known as "verde antique." It contains serpentinized pyroxene and some graphite. Many years ago the quarry was operated by Daniel Lynch and some of the stone was shipped.

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New York State Museum

JOHN M. CLARKE, Director

GLACIAL GEOLOGY OF THE COHOES QUADRANGLE

By JAMES H. STOLLER

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1920

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The University of the State of New York
Science Department, November 9, 1918

Dr John H. Finley
President of the University

SIR:

I beg to communicate herewith and to recommend for publication, as a Bulletin of the State Museum, a manuscript entitled *Glacial Geology of the Cohoes Quadrangle,* which has been prepared, at my request, by Prof. J. H. Stoller.

Sincerely yours

JOHN M. CLARKE
Director

Approved for publication, November 14, 1918

President of the University

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GLACIAL GEOLOGY OF THE COHOES QUADRANGLE

BY JAMES H. STOLLER

INTRODUCTION

The period of geological history known as the Glacial or Pleistocene Period and characterized by the extension of a great ice sheet from the region of Labrador southwestward beyond the boundary of the State of New York has its record in the materials left by the ice and by the flooded waters following the melting of the ice.

This bulletin deals with the Pleistocene geology of the area of the Cohoes quadrangle. The materials for study consist in general of the mantle of clay, sand, gravel and boulders that overlies bed-rock. The distribution and mode of arrangement of these materials and the surface forms which they exhibit — whether hills of definite topographic features, terraces along the courses of streams, or slopes bordering ravines and valleys — reveal the agencies which brought these materials to their present locations and gave them their present forms. To the extent that the several kinds of earthy materials occur in separate areas of distribution, the mapping of the glacial deposits becomes, in a general way, a survey of soils. In the region here reported upon the dependence of soil composition upon geological origin is, over considerable portions of the area, somewhat close and the accompanying map is therefore of interest not only from the standpoint of geologic science but also that of agriculture. Thus the soils that originated as sediments, consisting of finely divided particles of clay and sand deposited in bodies of

water forming temporary lakes, at the close of the ice age, are of quite different character from the unassorted materials left from the melting ice. Some of the glacial deposits are also of economic importance in other ways, especially the clays extensively used for making bricks and the sands for building and molding purposes.

It may be noted that in other ways the industrial life of the people is dependent upon factors and conditions resulting from the changes wrought upon the country during the Ice Age. The largest city, Cohoes, owes its growth as a manufacturing center to the source of power afforded by the falls in the postglacial gorge of the Mohawk near its mouth. The villages of Schaghticoke and Valley Falls are similarly related in location and industry to the rapids of the Hoosic river where in its lower course it has carved a channel in rock, since the close of the glacial period. A further instance of the relation of human interests to conditions determined by glacial agencies is that of the restoration of an extinct glacial lake — Lake Tomhannock, on the Cohoes quadrangle — in order to form a storage reservoir for the water supply of the city of Troy.

The history of the drainage of the area, especially of the streams tributary to the Hudson, as deduced from the facts gathered in the present work, is of exceptional interest and throws light on some of the larger problems of the postglacial history of the Hudson-Champlain valley. The data bearing on these questions and a discussion of them are given in the body of this report.

PHYSICAL GEOGRAPHY AND GENERAL GEOLOGY

The Cohoes quadrangle is intersected by the Hudson river, which enters the area at about the middle of the northern border (latitude 43°) and flows southwestward and southward crossing the southern border (latitude 42° 45′) about 1 mile above the head of navigation of the river at Troy. The elevation of the river at the northern margin of the sheet falls between the 80 and 100 foot contour lines and at the southern border is less than 20 feet above sea level. The segment of the Hudson river here included belongs, therefore, to the upper or what may be termed the river portion proper, in distinction to the lower, or estuarine portion, which is within the influence of the ocean tidal movements.

In considering the geology of this portion of the Hudson valley it is helpful to distinguish at the outset between the preglacial valley which is now largely filled with sand and clay deposits of Pleistocene age and the present valley which belongs to the recent

period, that is, has been formed since the time of the subsidence of the body of glacial waters in which the sands and clays were deposited. The preglacial valley is cut in rock and is somewhat complex in form, consisting of a broad and open outer portion and an inner portion with steeper slopes. The whole, as a physiographic

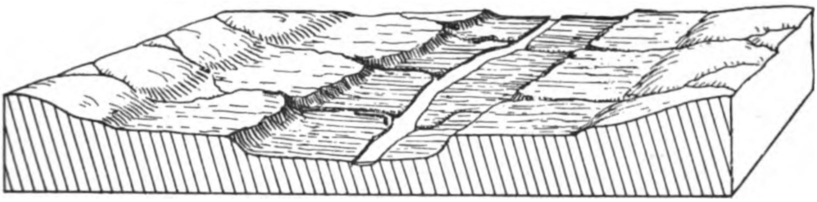

Fig. 1 Diagram showing preglacial topography of the Hudson valley

feature, may be described as a gorge within a valley. This ancient rock valley represents the erosive work of the Hudson river in the Cenozoic (Post-Cretacic) era of geologic time and its double form is considered to be the result of an uplift of the general region following an earlier period of valley erosion. Its form and dimensions are now evidenced by outcrops of rock that occur near the lateral border of the clay and sand area and by the depths of the ravines which have been cut into the filling of the ancient rock valley and in places into the underlying bedrock. From these data it is shown that the ancient valley has an average breadth of between 4 and 5 miles and a depth in its middle portion of 200 feet or more. The width of the inner valley or gorge is on the average about 2 miles: its depth, of course, is the same as that of the broader valley.

The present valley of the Hudson, as here considered, is the broad depression on the bottom of which the river flows in a more or less winding course and the sides of which are the steep clay banks which rise 100 feet or more above the valley bottom. The present valley lies within the old rock gorge, its bottom being coincident with the middle portion of the floor of the latter. The present channel of the river, however, in the greater part of its extent, is cut into the floor of the old gorge, forming a shallow rock gorge representing the erosive work of the river in the recent period. The present valley bottom, threaded by the channel, has a width varying from three-fourths of a mile to one and one-half miles.

Where the river enters the quadrangle and for several miles southward this bottom is an alluvial plain, but from Stillwater to

the southern edge of the sheet the valley bottom stands generally above the level of overflow of the present river and its materials are chiefly of glacial origin or, in large areas, of bared rock or residual soils derived from the rock in the recent period.

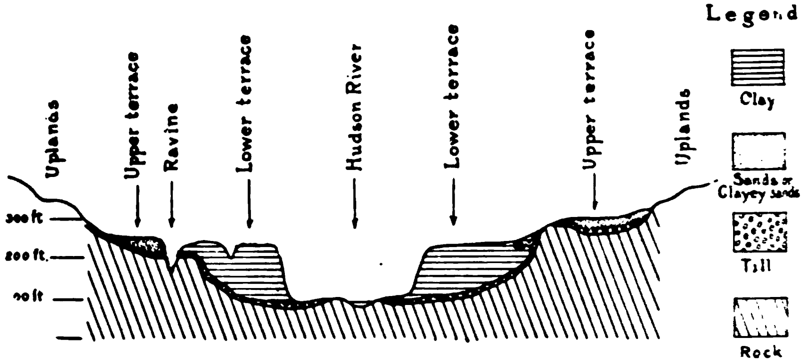

Fig. 2 Section across the Hudson valley showing present surface features and relations of Pleistocene deposits to the underlying rock surface. The surface line is drawn to scale along an approximately east-west line taken about 3 miles south of Mechanicville.

Rising from the flat valley bottom on either side are steep slopes or bluffs, the materials of which are the stratified Pleistocene clays. From the summit of these bluffs, extending outward from the valley, are expanses of clay or sandy clay lands forming terraces. These terraces occur on both sides of the river at approximately corresponding levels, showing that they are remnants of a continuous plain that has been divided by the erosive work of the Hudson waters.

At the outward margin of these terraces the surface again rises, in some places rather abruptly and in other places gradually, forming a slope the rise of which is, as a general average, about 60 feet. Outward from the summit of this slope the surface again becomes flat or moderately sloping toward the valley and extends north and south somewhat as a bench or terrace normal to the river valley. This area, which will be referred to in this report as the upper terrace, consists of soils in which there is a larger proportion of sand than in the clay soils of the lower terrace. Beyond the outward limit of the upper terrace rise the uplands areas, the surface materials of which consist chiefly of till or materials derived from or left by the melting of the ice sheet.

Within the limits of the quadrangle the Hudson receives its largest tributary, the Mohawk river, from the west; and one of its largest tributaries from the east, the Hoosic river.

Plate I

Cohoes Falls. View from south bank, showing stream at low water occupying a narrow channel made by pothole erosion.

The segment of the Mohawk valley included in the southwestern part of the sheet belongs to the portion of the river (from Aqueduct near Schenectady, to its confluence with the Hudson) which occupies a postglacial valley.[1] The evidence of this is that the valley of the river, for a distance of 5 miles east of Aqueduct, is a gorge cut into the rocks and extending like a trench across the face of the country. There is no buried old valley, as in the case of the Hudson, lying outside the present valley. These features, which are well marked in the upper portion of the preglacial valley, are considerably modified in the lower portion. The course of the stream becomes irregular, the valley broadens and its slopes are less steep. These differences are due in part, especially in the segment of the valley falling within the Cohoes sheet, to structural features of the underlying rocks which here have their strata steeply inclined, dipping to the east, and in part to the fact that the Mohawk here enters the region of the old eroded rock valley of the Hudson. The river has, however, lowered its bed into the floor of the rock valley and in the last 3 miles of its course occupies a rock gorge. This portion of the river is marked by the well-known falls at Cohoes.

On the north (northeast) side of the river, stretching back from the summit of the gorge, there is an area, several square miles in extent, consisting of rock with a thin covering of clayey soil. This area has evidently been swept by the currents of the Mohawk when the river flowed at a level about 80 feet higher than its present bed, above the falls. The Pleistocene clays were removed and subsequently the existing clays were formed as a residuum from the weathering of the exposed rock surface. On the south side of the gorge only a narrow strip of the Pleistocene clays was removed by river erosion and the surface topography of the clay formation exhibits terraced forms, normal to the Hudson valley, as above described. See figure 7, page 36.

About three-fourths of a mile below the falls at Cohoes the Mohawk waters divide into several divergent streams which enter the Hudson by as many channels, thus forming a group of rock islands. These multiple mouths of the Mohawk are interpreted as originally delta distributaries which became intrenched in the underlying weak rocks after the removal of the delta deposits from their beds by erosion.

[1] Stoller. Glacial Geology of the Schenectady Quadrangle. N. Y. State Mus. Bul. 154, p. 11.

The Hoosic river, which has its sources on the western slopes of the mountainous region of the New York-New England border, enters the quadrangle in the northeastern quarter of the sheet and flows in a meandering course westward and northward, discharging into the Hudson at the head of the rock channel at Stillwater. The river valley except for a short length west of Johnsonville, is everywhere bordered by deposits of sands and gravel. Westward from Schaghticoke the river penetrates an immense mass of fine gravels and coarse sands which clearly originated as a delta built by the river into the body of waters that occupied the Hudson valley in late glacial times. The delta formation is of the characteristic triangular shape and at its base, fronting the Hudson valley, has a breadth of about 7 miles. Its areal extent may be estimated at 20 square miles.

In its course through the delta the present river is flanked by a series of terraces which rise at successively higher levels to the general summit level of the Pleistocene clays of the Hudson valley. A fuller description of the Hoosic delta, together with a discussion of its development and that of the system of terraces, will be given further on in this report.

A valley of exceptional interest from the standpoint of Pleistocene history is that which enters the Hudson valley from the west at Mechanicville. It is occupied by a small stream, Anthony kill, which in its present size is quite out of proportion to the breadth and depth of the valley. Anthony kill is the outlet of Round lake (see map, p 46) which in turn receives the outlet stream of Ballston lake, the latter lying at the bottom of a preglacial channel that communicates with the valley of the Mohawk east of Schenectady. There is quite conclusive evidence[1] that in late glacial times waters from the flooded Mohawk river coursed through this system of channels, discharging into the waters of the Hudson valley at Mechanicville. At a later time the Mohawk became established in its present course, and Anthony kill, draining the old channel as far back as the divide at the head of Ballston lake, is the shrunken remnant of the much larger stream through whose erosive work the present relatively large valley was formed.

As in the case of the Mohawk river, Anthony kill, entering the Hudson from the west, runs athwart the ancient rock valley of the Hudson. From Willow Glen eastward the floor of the valley is

[1] Stoller. Op. cit. p. 29-31; Fairchild. Pleistocene Uplift of New York and Adjacent Territory. Bul. Geol. Soc. of Amer., 27:251.

rock with a slope to the east of 80 feet in a distance of 2 miles. This is a part of the old valley floor, though now reduced by erosion.

In somewhat sharp contrast to the system of valley depressions thus far described are the uplands portions of the quadrangle. The uplands, as here referred to, stood above the level of inundation by the glacial waters and are clearly marked off from the area covered by waters both in respect to topographic features and the materials of which the soils are composed. The Pleistocene deposits filling the valley depressions, although now trenched by the great river courses and ravined by the minor streams, still represent, especially where deltas have been developed, the general level of the body of waters in which they were laid down. The uplands stand out in marked relief above this level. This contrast is very striking in the field when one stands at a point commanding a view of the two topographic regions.

The surface of the uplands is in general highly irregular. This is due primarily to the structure of the underlying rocks and to the effects of differential erosion upon the rock surfaces in preglacial times. The rocks are shales and sandstones of the Cambric and Ordovicic series and possess the folded structure and alterations due to metamorphism common to these rocks as they occur in the Hudson valley region. The strike of the folds is in a general north-south direction and this gives to many of the hills an elongated form, with long axes trending north and south. Two of the highest elevations, Rice mountain and Mount Rafinesque, in the middle portion of the southern third of the quadrangle, are, however of irregular, massive form. The highest elevation of surface is near the southeastern corner of the sheet where a ridge of steeply inclined strata attains the height of 1265 feet.

The surface of the uplands bears evidence of considerable modification by ice agencies. Many of the hills which show exposures of rock have somewhat even and smoothed outlines indicating the effects of abrasion by moving ice. In many cases the more smoothed surfaces face north, indicating the wear of the rock on the side from which the ice approached. In some instances low hills of topographic form approaching that of drumlins are found to be reduced rock hills, partly covered by glacial till. The group of hills west of the Saratoga battlefield near the northern edge of the sheet is of this character.

In general, the minor topographical aspects of the surface of the uplands are due to deposits of glacial origin, a description of

which is given below. These deposits form a mantle everywhere overlying bedrock, except where ridges and masses of rock protrude through the covering. The relief is that of a region in the mature stage of erosion but with irregularities of surface somewhat reduced by ice abrasion and by deposits of Pleistocene and recent age.

The drainage of the uplands region is mainly through small streams that flow directly to the Hudson or to the tributary rivers, named above. The streams that discharge into the Hudson show interesting changes in the character of their valleys as they pass from the uplands areas and cross the clay and sand formation. In their upper courses the streams are adjusted to the slopes of the surface and to underlying rock structure and they wind between the hills in open valleys, but as they debouch upon the plain of the clay and sand deposits their courses become more direct and their valleys narrower and deeper, forming ravines. It is probable that in their upper courses the streams occupy mainly preglacial valleys while obviously the ravines have been formed in postglacial times, that is, since the withdrawal of the waters in which the clays and sands were deposited.

The largest stream of the uplands region is Tomhannock creek, which has its rise near the southeastern corner of the quadrangle and flows northerly, emptying into the Hoosic river about 3 miles from its mouth. In the upper and again in the middle part of its course this stream follows broad depressions of surface which are the beds of extinct lakes. In its lower course it penetrates the Hoosic delta. A fuller statement of the steps of glacial history recorded in these physiographic features is given later.

DESCRIPTION AND INTERPRETATION OF THE DEPOSITS

Till or ground moraine. Till or rock debris derived from the ice sheet, whether left from the bottom or deposited from the ice at the time of melting, forms the mantle of materials overlying the bedrock generally. In the uplands it constitutes the greater part of the body of soils and subsoils but in the great valley depressions it is covered by the lacustrine clays and sands, except where the latter have been swept away by stream erosion. It includes all rock fragments derived from the ice of whatever size, from boulders to grains of sand and particles of clay.

The boulders are nearly all of rock different from the underlying country rock, showing that they were brought by the ice from regions lying to the north. But the finer parts of the till include many bits of the local rock and there is everywhere a noticeable correspondence between the predominant mineral elements of the till and those of the nearby exposures of the underlying rocks. As the country rocks of the region are largely shales (slates), they give to the soil a predominantly clayey character. It is in general well adapted to agricultural purposes.

The thickness of the till varies greatly in different parts of the area. Near the summit of the main rock ridges and masses the till sheet is generally thin and, as noted above, there are frequent exposures of bare rock. In places these exposed rocks have undergone decomposition to a considerable extent, and the residual products, having fallen or having been washed from the slopes of the rock surfaces, are added to the materials of the till.

In the valleys and depressions between the rock hills the till is in general thicker than on the tops and sides of the hills. This may be due in part to the valleys having been occupied by the ice for a longer time than the hilltops or to a relatively greater amount of till having been originally lodged in the valleys, but it is probably also due to removal of till from the hills by washing. The occurrence of boulders resting on the exposed rock of the hills is evidence of this, the finer materials of the till having been washed away.

In contrast with rock hills veneered by till are those hills which are apparently made up wholly of till. Many of the low hills, and some of larger proportions, are of this character. The most noticeable one is that southeast of South Easton, marked by a depression contour on its western slope. As far as could be determined by inspection, the materials of this hill are till and the depression is due to irregularity of heaping of the debris derived from the ice. Another hill apparently composed wholly of till is that north of Crandall Corners and crossed by the road. This is of the type of a drumlin. An interesting drumlin is that which occurs on the floor of the Hudson valley, east of the river and directly opposite Bemis Heights. It stands as a conspicuous oval hill, strewn with cobbles and boulders, rising above the level of the alluvial plain. It is evident that this hill was once covered with lacustrine clays and that when the latter were swept away by flooded stream erosion, the more resistant materials of the hill remained.

Hills of Sand and Gravel. *Kames.* In the uplands region there are a number of isolated groups of hills, composed mainly of sands and gravel and presenting the characteristic features of kame topography. Their locations are shown on the accompanying map. The largest of these kame areas lies northward from the valley of the eastern branch of Tomhannock creek and near the village of that name. The surface of this area, made up of hills and hollows of irregular shapes and without order of arrangement, is conspicuously different from that of the surrounding country, the features of which are largely controlled by the underlying rock surfaces. Many of the hills have steep slopes and a degree of evenness of front that indicates deposition of the sand and gravel materials against a stationary mass of ice.

These groups of hills are interpreted as recessional moraines, marking a temporary cessation of retreat of the general ice sheet at the time of melting in the localities where the heaps of debris occur. In the case of the moraine just described it seems probable that its development was incident to the slower melting of the thick ice that filled the preglacial valley now followed by the creek. There is evidence that the moraine originally extended farther south across the valley and that it has been reduced at its southern edge by stream erosion, the finer materials having been carried by the stream to glacial Lake Tomhannock, there building a delta, as described below.

Ridges. In a number of localities there were observed accumulations of sand and gravel with admixture of clay and fragments of slate rock having the general topographic form of ridges. In some of them, as the one near Melrose and that north of Speigletown, the materials, as exposed in gravel pits, show a stratified arrangement. The location of these ridges (see map) presents a certain uniformity; that is, they are all located on the uplands but within a short distance from the clay and sand deposits of the Hudson valley. Their elevation above the latter varies from 20 to 60 feet. The direction of the ridges is in general parallel with that of the edge of the valley deposits.

The inference drawn from these data is that these ridges represent deposits made marginal to the lobe of ice that occupied the Hudson valley after the disappearance of the general ice sheet from the uplands. A fuller statement of the evidence of the persistence of an ice lobe in the Hudson valley long after the melting of the ice from the uplands will be given later in this report. It is believed

that in places accumulations of materials from the melting of the ice lobe at its margins gave rise to lateral morainic deposits, thus forming these ridges.

Glacial lakes. In the middle eastern and southeastern rectangular divisions of the Cohoes sheet there are two elongated tracts conspicuous by their flatness as contrasted with the highly irregular surface of the uplands country surrounding them. The more northerly of these tracts, or intervales, extending from near Raymertown northwesterly and having a length of about 5 miles and an average breadth of about one-half of a mile, has recently been converted into a reservoir for the public water supply of the city of Troy. This was accomplished by constructing a dam across Tomhannock creek at the place where this stream, after following in meandering course the length of the flattened area, entered a gorge about 1 mile south of East Schaghticoke.

Lake Tomhannock. There is quite conclusive evidence that this area, now an artificial lake, was in early postglacial times a natural lake. The stream that flows past the village of Tomhannock built a delta in this postglacial lake which now shows quite perfectly as a sand and gravel bench or terrace at the 400-foot level and bordering that arm of the artificial lake which extends northeasterly toward Tomhannock. The materials of the terrace are well exposed in road gradings and show horizontal stratification.

It is believed that this glacial lake (which may be named Lake Tomhannock) originated through the gathering of waters in an old stream valley across the course of which a dam was formed by deposits from the ice sheet. This preglacial stream flowed northwesterly from near Raymertown and then southwesterly toward Melrose and the glacial dam was formed in the latter portion of the stream course and near where at present the divide at the 400-foot level occurs. For a time the waters of the glacial lake, held back by the ice front, overflowed the dam and the lake had its outlet in the stream that flows southwesterly past Melrose to the Hudson river.

When the ice front had retreated as far north as the plain south of East Schaghticoke, a lower outlet for Lake Tomhannock was afforded in the line of its present course. The outflow stream thus established degraded its bed and eventually the waters of the lake were drained off.

The other intervale, farther to the south, also marks an extinct glacial lake. This tract continues southward on the Troy sheet and

this southern extension is drained by Quacken kill which joins Poesten kill, the latter stream discharging into the Hudson river at Troy. It is inferred that in preglacial times a stream heading near Raymertown flowed southward, developing the valley which now forms the intervale area and that at the close of the Ice Age a barrier of glacial deposits was left across this valley at the place where the divide now occurs, about 1½ miles from the edge of the sheet. Waters were ponded north of this barrier and this glacial lake had its outlet in a stream that flowed past Raymertown and emptied into Lake Tomhannock. This outlet stream had a fall of 100 feet and, through downcutting, the lake was finally drained off. The axis of drainage of the two glacial lakes thus led to the extension of Tomhannock creek southward to its present source.

A chain of small glacial lakes occupying depressions in the general surface of the country developed in the region southwest of Rice mountain beginning south of Haynersville. These were eventually drained away by Deep kill, which has cut a deep gorge on the eastern flank of the mountain. On the map two of these areas have been designated as extinct lakes and the others as swamps, the latter being partially covered with standing water.

Lake Hoosic. There is quite good evidence that a temporary glacial lake existed in that portion of the Hoosic valley crossed by the eastern margin of the sheet. North of the river there is a plain, traversed by Whiteside brook, the materials of which are sand and fine gravel. They are distinctly stratified in arrangement as shown in cuts along the Greenwich and Johnsonville Railroad. The general elevation of this plain is 420 feet. South of the river in the neighborhood of Johnsonville the surface materials are of sand and gravel character and in places rise to about the same level as the plain opposite.

It is believed that these deposits represent a glacial lake, the waters of which gathered behind a dam across the preglacial Hoosic valley made by drift, or deposits from the ice sheet. About a mile below Johnsonville till rises from the left bank of the river to the 440-foot level and on the opposite side there is a hill of till 420 feet in elevation. The latter hill slopes toward the river, the stream curving at its base. It is inferred that a mass of till of which these hills are remnants originally extended across the valley forming a dam behind which the waters were held in check, converting this portion of the valley into a temporary lake.

THE LAKE ALBANY DEPOSITS

The body of glacial waters in which the stratified clays of the upper Hudson valley were deposited was named by Woodworth Lake Albany. He limited the extent of Lake Albany to the waters represented by the deposits extending from near Rhinebeck on the south to the Fort Edward district on the north[1] (north of the Cohoes quadrangle). In his view, the gathering of the waters of Lake Albany was pari passu with the melting of the ice sheet in its retreat northward in the middle Hudson valley.

Another view is that the deposits are estuarine, having been laid down in the sea-level waters which extended as an inlet up the Hudson valley from the ocean at New York.[2]

Fairchild has stated the conclusion that the body of waters in which the Hudson valley clays and sands were deposited was at sea level and at its highest development formed a strait connecting the oceanic waters which then occupied the St Lawrence valley with the ocean at New York. "As the ice front melted back the ocean followed it and flooded the valley. The waters were at first the Hudson inlet; later, the Hudson-Champlain inlet; and finally, the Hudson-Champlain strait."[3]

In this report we shall refer to the waters as Lake Albany, though without implication as to the correctness of the first mentioned of the above interpretations. We shall, however, below call attention to certain facts of topography which seem to afford clear proof that the body of waters in question subsided (that is, dwindled to a river) while drainage from the great interior lakes (Algonquin-Iroquois stage) was still through the Mohawk valley. The inference is that Lake Albany disappeared prior to the opening of the St Lawrence channel (as due to ice melting); that is to say, prior to the invasion of marine waters in the St Lawrence basin.

The writer would also state that in this report the term "subsidence" is used as pertaining to the fact of the withdrawal of the Lake Albany waters but without implication as to whether the

[1] Ancient Water Levels. N. Y. State Mus. Bul. 84, p. 177 and 242, 1905.

[2] Merrill, Quaternary Geology of the Hudson River Valley. 10th Annual Rep't of the State Geol., 1890. Peet, Glacial and Postglacial History of the Hudson and Champlain Valleys. Journal of Geol., 12:640. 1904. This author considers two alternation hypotheses: (1) the water body was a lake made by a barrier at the south, (2) the water body was an arm of the sea.

[3] Fairchild. Ann. Rep't of N. Y. State Geol. 1912, p. 24.

cause of the subsidence was the removal of a barrier at the south which held in the waters or to regional uplift.

The Lake Albany deposits comprise (1) the mass of stratified clays and sands whose surface forms the terraced slopes of the Hudson valley and (2) the sands and gravels of the Hoosic delta.

The clay and sand formation, as already stated, forms the filling of the ancient rock valley of the Hudson. The lower beds of the formation consist predominantly of clay and are the source of the well-known brick clays of the upper Hudson region. As seen in the pits at the brick-making plants, the clays are fine grained, evenly laminated and of a bluish color below passing to yellowish above. As exposed in mass at the slopes fronting the river valley or along the ravines, the weathered surfaces are of a buff or yellowish color. The compact clays make up perhaps the lower 100 feet of the formation, above which they grade into sand, clays or clayey sands. The latter, in certain localities (as 1 mile southwest of Mechanicville) have the composition requisite for molding sands.

Farther back from the river the materials of the Lake Albany deposits are coarser and consist more largely of sands. In places, however, the clay constituent still predominates and there are tracts of considerable extent at or near the 300-foot level, as west of Melrose, where the lands are of clayey character.

The surface of the clay and sand formations is marked by striking topographic features. These are (1) the terraces of which an upper and a lower are distinguished and (2) the ravines which cross the terraces, dividing them, especially the lower one, into segments.

The upper terrace is less well defined than the lower. In places (as west of Cohoes and southwest of Mechanicville) it appears as a nearly level expanse, one-half of a mile or more in breadth, bordered at its outward side by a slope toward the uplands and at its side toward the river by a more gradual slope to the level of the lower terrace. This description applies generally also to the upper terrace on the east side of the valley as it appears north of Crandall Corners and northwest of Melrose. In other places (as west of Stillwater) the upper terrace is less perfectly expressed, being narrower and with surface falling toward the river. In places, also, as at the Saratoga battlefield, the level of the terrace is broken by hills of till (or till-covered rock hills) which rise above the lacustrine deposits. East of Lansingburg the upper terrace (as also the lower) disappears as a distinct form feature, the steep rock

wall of the valley here controlling the topography. These modifications of the terrace form (apart from the effects of underlying rock features) are clearly due in part to postglacial erosion but probably in larger part to the conditions under which the materials were laid down.

DEVELOPMENT OF THE UPPER TERRACE

It is believed that the sands and clays of the upper terrace were in large part laid down at that stage of the melting of the ice when the uplands had been bared, while a broad lobe of ice still lingered in the Hudson valley. In the lateral depressions, between the central mass of ice and the bared slopes of the valley, waters gathered and flowed southward discharging into the open lake waters along the dwindling southern limit of the ice lobe. These currents bore sediments partly derived from the debris of the melting ice and partly received from the tributary streams draining the bordering uplands. The finer parts of these sediments were deposited mainly where the currents were checked by the quiet waters of the lower end of the marginal channel, or embayment between the ice lobe and the shore of the lake. The coarser materials were deposited in the bed of the channels. Also as the latter shifted in position, due to the shrinking of the lobe of ice, the deposits were made progressively farther inward from shore. In this way the accumulations acquired the form of a shoal platform with face sloping toward the middle of the lake. With the subsidence of the lake waters, at a later time, the shoal became a terrace of similar slope. (See fig. 3, page 22.) At times bodies of comparatively static waters were held in portions of the lateral depressions conforming to topographic features of the adjoining slopes and to irregularities of the ice border. When tributary streams from the uplands discharged into these quiet waters deposition took place, forming deltas. With the subsidence of the waters, at a later time, these deltas emerged as terraces of more even and level surfaces than those described in the preceding paragraph. It is believed that an example of a terrace form developed in this way is the flat area northwest of Melrose at the 300-foot level at its outer border.

On the north side of the Mohawk river and both north and south of Anthony kill the plain of the upper terrace becomes continuous with that of Lake Albany deposits bordering these streams and extending westward to the general sand plain region of the Schenec-

tady quadrangle. The terrace surface, in these westward extensions, shows a gradual increase in elevation.

The general or average elevation of the upper terrace may be stated as 300 feet. For the most part the 300-foot contour line of the sheet marks the outer border of the terrace plain, although, in places, the lacustrine deposits rise to a higher level. As a rule no definite line of contact of the clays and sands with the till of the uplands can be observed in the field, and in mapping this boundary has been drawn somewhat arbitrarily. As pointed out by Fairchild,[1] the summit level of the body of glacial waters was often higher than the plain of the deposits built into it. In the Lake Albany waters the deltas formed at the mouths of the larger streams, now represented by extensive sand plains, as that south of Schenectady (Mohawk delta), north of Ballston (Hudson delta) and that of the Hoosic delta, described below, probably indicate closely the height of the lake waters. (Present differences in elevation are to be accounted for by postglacial deformation.)[2] But the deposits made in Lake Albany, other than the great deltas, were not usually built up to water level. Thus the plain of the Hoosic delta near its head, as in the broad expanse northwest of Schaghticoke, stands 340 to 360 feet elevation, while the upper terrace which extends northward from the delta has an elevation of 320 feet. This difference is interpreted as due to a less amount of deposition taking place in the marginal channels, in the early stages of the development of the lake, as above described, than at the mouth of the large rivers, at the later stage when the deltas were built. Also differences in elevation of the upper terrace in different localities are understood as due primarily to differences in amount of sedimentation.

The lower terrace is a quite definite topographic feature. On the west side of the river it is continuous from the northern to the southern margin of the sheet, except as broken by the numerous ravines that cross it and where, in the localities of Mechanicville and Waterford, broad stretches of the terrace were swept away by the flooded Mohawk waters of late glacial times. On the east side of the river the terrace shows as a distinct form feature except where interrupted by the Hoosic delta and by the steep rock wall of the valley at Lansingburgh. The terrace is best developed in the middle part of the sheet where it attains a breadth on each

[1] Bul. Geol. Soc. of Amer., 27:239.
[2] Stoller. Glacial Geology of the Saratoga Quadrangle. N. Y. State Mus. Bul. 183.

side of the valley of a mile or more. These terrace plains form evident and striking features of the landscape. In the field, to the observer looking north and south and ignoring the depressions of the gullies, the terrace surface appears as one level expanse; or, looking across the valley, as a bench broken by the ravines and with the upper terrace slope and plain and the rising hills of the uplands in the background.

DEVELOPMENT OF THE LOWER TERRACE

The conditions under which the lower terrace was developed are believed to be as follows: With the disappearance, through melting, of the ice lobe from the Hudson valley, the middle portion of the valley became the seat of sedimentation. It had already received debris derived from the melting of the ice lobe, together with some accessions of finer sediments borne by the currents flowing in the marginal channels and checked by the quiet waters of the embayments lateral to the terminal portion of the ice lobe. The conditions of an established body of lake waters now permitted deposition from the currents normal to the lake. As the outlet of the lake was at its southern end, we may assume constant southward flowing midlake currents. These currents, moving in a body of water of considerable magnitude, were of low velocity and carried only fine sediments. Under the fluctuations incident to varying seasonal, climatic and other physical factors, deposition of these sediments took place and thus layers of silts and fine sands were laid down on the floor of the middle portion of the lake.

At length came the time of the subsidence of the Lake Albany waters. At the first stage of subsidence the lateral portions of the lake bottom had emerged as land surface, forming the upper terraces, above described. The erosion of the surfaces of these terraces immediately began and many small streams, heading in the uplands, extended their courses across the terraces and discharged into the shrunken lake. The sediments brought by these streams to the lake were distributed over the same area of the lake floor that had received deposits from the midlake currents. From these two sources were derived the silts now forming the clays of the lower terrace. The emergence of these deposits, thus giving rise to the present terrace, was due to a further subsidence of the Lake Albany waters.

The accompanying diagrams are believed to represent the successive steps in the development of the upper and lower terraces, ending with the production of the present features of the valley.

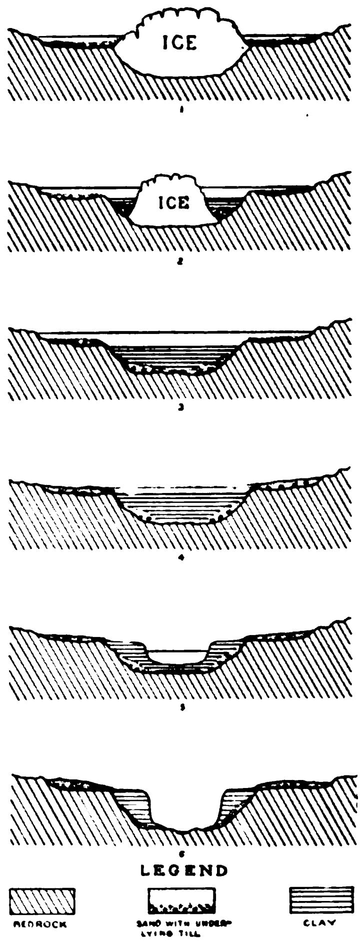

Fig. 3 Diagrams showing the conditions of deposition of the sands and clays of the Hudson valley and the development of the terraces

No. 1 shows the ice lobe occupying the inner preglacial valley of the Hudson and the waters (embayments of Lake Albany) filling the depressions between the lateral margins of the ice lobe and the rim of the outer valley. Deposits made in these waters were largely of sands. No. 2 shows the shrunken ice lobe and the consequent broader embayments. Depositions of finer sediments, mainly clays, were made in the deeper and more quiet waters. No. 3 shows the conditions when Lake Albany was at the height of its development. In the quiet mid-waters of the lake abundant clay sediments were deposited. No. 4 shows conditions at the end of the first stage of marked subsidence of the lake waters. The outer portions of the lake bottom have emerged forming the present upper terrace. No. 5 shows the conditions after the second stage of marked subsidence. The lower terrace has emerged. No. 6 shows the deposits in their present relations and the present topographical features of the valley.

The Hoosic delta. The Hoosic delta, like the other deltas built by large streams which discharged their sediments into Lake Albany, in its present surface features bears the character of a sand plain. The continuity of the plain is broken, however, by the valley of the present river which has sunk its bed deeply into the sands and, through meandering, swept away a broad path through the delta. The marginal limits of the delta plain are indicated partly by differences in the topographic features of the delta, as contrasted with the terraced deposits above described, and partly by differences in the character of the materials of the two formations. In general, the delta materials as seen at the surface are coarser and less coherent than those of the terraced areas, the proportion of sands and fine gravels being much larger.

The shape of the delta is that characteristic of this type of constructional formation. The materials are spread out fanlike from the original head of the delta or place where the river debouched into the lake. This may be taken as at Schaghticoke. The outward margin of the delta mass, fronting the Hudson valley, is somewhat of the form of an arc but this has been considerably modified by river erosion. The Hudson currents, deflected eastward from Bemis Heights, have cut deeply into the northward extension of the delta border. Also, at an earlier time, the Iroquois-Mohawk currents which followed the present course of Anthony kill, sweeping across the subsiding waters of Lake Albany, cut deeply into the marginal lobe of the delta at Reynolds forming the upper and lower erosion terraces to be described below. (Further reference to this stage of Pleistocene history will be given below.)

The surface of the delta plain varies much as to composition of materials and minor topographic features. The soils are for the most part too deficient in clay constituents to be valuable for agriculture. Considerable areas are left uncultivated and there are tracts of coarse sands where wild vegetation is scanty. The lack of coherence of the soil particles has resulted in extensive gullying of the surface over considerable areas. In the region east of Reynolds the plain is deeply dissected by many ravines producing the irregularities of surface indicated by the contour lines of the sheet.

The above description applies to the surface materials and features of the delta where the plain has not been reduced by river

erosion. Where the Hoosic river has cut deep into the delta, forming a succession of terraces on either side of the valley, thus exposing the materials of the delta at different levels and at varying distances from the head of the delta at Schaghticoke, they differ considerably from the materials of the surface of the plain. In general, the terraces of the lower levels are of mixed clay and sand composition, forming soils which are well adapted for farming and gardening. For instance, the extensive flat at the 100-foot level crossed by the road running northeasterly from Reynolds is composed of fine-grained soils of high fertility. The materials of the terrace plain on the opposite side of the river, beyond the alluvial flat and rising to the 140-foot level, are also finely divided and include a considerable proportion of clay in their composition.

The fine sands and clays, lying at the base of the delta deposits and far out from the head of the delta, are interpreted as the bottom-set beds of the formation. They were laid down at an early stage in the building up of the delta, representing the finer sediments borne by the Hoosic river and dropped where the currents were checked by the quiet waters of the body of the lake.

The materials of the higher terraces become progressively coarser in order of elevation and of nearness to the head of the delta. This is well shown to the observer who follows the road south of the river, beginning where the road crosses Tomhannock creek and continuing eastward and southward to the 360-foot level of the delta plain beyond where the highway crosses the railroad.

Fig. 4 Profile of terraces in delta of Hoosic river. The terraces south of the river are shown on a line extending from the delta plain west of East Schaghticoke to the Hoosic river at the mouth of the Tomhannock creek; the terraces north of the river on a line extending from the latter point northeasterly to the delta plain northwest of Schaghticoke. See lines on map.

Thus the materials of the successive terrace plains were noted as follows: 140-foot terrace, sandy loam; 180-foot terrace, coarse sandy or loamy soil; 220-foot terrace, fine to coarse gravel; 320-foot terrace, gravel, largely uncultivated; 360-foot level (south of railroad), sand and fine gravel. The materials of the terrace plains on the opposite side of the river are predominantly sand and gravel, although the extensive plain at the 340-foot level has a considerable admixture of clay. To the east of the ravine, however, this plain gradually merges into an area of blown sands.

The coarse sands and gravels making up the middle layers of the delta formation and rising well toward its surface are interpreted as the fore-set beds. They are the coarser sediments which were deposited at first at the head of the delta and then successively added to, thus building up the delta progressively toward the body of the lake.

A section of the lower and middle beds of the delta, together with the underlying till, is shown on the right bank of the river about 1 mile below the gorge west of Schaghticoke. At the base there is a thickness of about 40 feet of materials of bluish color, mixed composition, including boulders, and without evident stratification. Above this and somewhat sharply defined from it, though without evident unconformity, are beds of yellow sands with approximately horizontal stratification, as seen in this section. There is an exposure of perhaps 30 feet of these sands as seen in nearly vertical section, and at a higher level the sands are continued on a sloping surface.

The elevation of the highest terrace plain of the delta is about 360 feet. The extensive plain northwest of Schaghticoke, bisected by the ravine, is 340 feet at its inner margin and rises to 360 feet at its outer margin. Southwest of Schaghticoke there is a narrow but distinct plain (crossed by the road to Schaghticoke hill) which is at 360 feet elevation. It is believed that these plains represent the level of the waters of Lake Albany. The former has an areal extent of several square miles and it is scarcely open to question that its materials were laid down below or at the level of the lake waters. It evidently consists of the top-set beds of the delta which were spread out horizontally over the fore-set beds. It will be noted that this elevation is considerably above that of the general or average elevation of the upper terrace of the body of deposits in the lake north and south of the area of the delta.

We have now to consider the sand and gravel deposits which border the Hoosic valley for several miles eastward from Schaghticoke. At East Schaghticoke these deposits are 380 feet in elevation and the village of Valley Falls, one and one-half miles to the east, is built on a river terrace of the same elevation. Also on the north side of the river and farther to the east there is a distinct terrace of sand and fine gravel. This terrace is sharply distinguishable, both in regard to materials of composition and topographic form from the hill of till adjoining it to the east and which formed a part of the dam of glacial debris behind which were ponded the waters which formed the glacial lake north of Johnsonville.

These deposits are interpreted as a valleyward extension of the delta and as representing that portion of the delta which was built up above the level of the general delta platform of the lake. This principle of delta growth has been stated as follows: "At the same time the channel of the stream above the original head of the delta is aggraded, for the current there is checked by the aggradation of the delta. Thus alluvial deposits continuous with the delta are extended landward."[1]

DEVELOPMENT OF THE HOOSIC TERRACES

The river had built into Lake Albany a great delta, the plain of which had been raised above the level of the water at the head of the delta, near Schaghticoke, and stood very slightly below the water level for a considerable distance outward from the head. When at length Lake Albany began to subside this portion of the delta plain, covered by shallow water, emerged as land surface. During the emergence the river maintained its channel across the added area but as the extent of the level or slightly sloping surface increased, the stream was gradually thrown into a winding course and eventually broad meanders were developed. The continued degradation of the bed of the river resulted in lowering the level of the plain within the belt of meandering. In the shifting of the channel of the stream from side to side terraces were left at the outer limit of each meander. These terraces were formed at successively lower levels according to the level of the lowering plain at each successive swing of the river.

The subsidence of Lake Albany by stages, bringing to the surface at different times added areas of the delta surface, was undoubtedly an important factor in the development of the terraces. It is possible that the slopes bounding some of the terraces represent in fact abandoned shore lines of the lake. The terrace on the north side of the river at the 280-foot level at its inner margin and bounded at its outer margin by the slope that separates it from the 340-foot level of the delta plain lends itself to this explanation. The contour lines that mark the 20 feet of slope trend abruptly to the northeast and can scarcely be interpreted as indicating the limit of a meander. The writer has not found it possible, however, on the basis of topographic evidence, to differentiate between the effects to be immediately connected with subsidence and those due to erosion and meandering as described above.

[1] Chamberlin and Salisbury. Geology, 1:189.

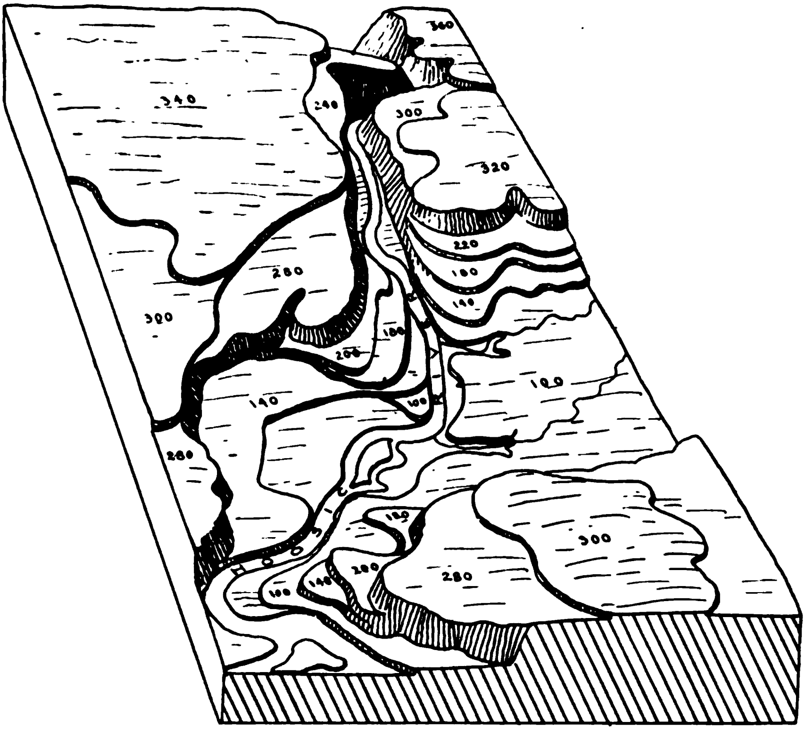

Fig. 5 Diagram showing terraces in delta of Hoosic river

EROSION TERRACES

Near Mechanicville on either side of the Hudson valley there is a well-defined terrace at the 200-foot level. These terraces are quite certainly of different origin from the other terraces bordering the valley and described above as the upper and lower terraces of the Lake Albany deposits. The terrace west of the river (southwest of Mechanicville) stands 40 feet below the lower lake terrace and is separated from the latter by a steep slope. It was evidently formed by the cutting down of the inner portion of the area of the lake terrace. The terrace on the east side of the river is likewise evidently a terrace of erosion having been carved out of the Hoosic delta deposits.

It is evident that the currents which formed these symmetrical erosion terraces issued from the valley now followed by Anthony kill. The west terrace has the location and trend of outlines which would result from erosion by a western tributary river occupying

this valley and discharging into waters flowing southward in the Hudson valley. The east terrace likewise has the location and form relations which would result from currents from the same tributary river sweeping across the Hudson valley waters and impinging against a frontal lobe of the delta mass.

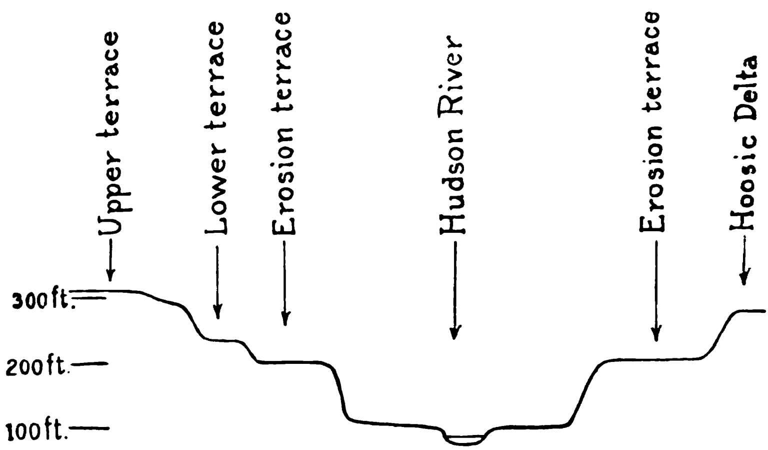

Fig. 6 Surface profile across the Hudson valley at Mechanicville showing the symmetrical erosion terraces. Horizontal scale and relief scale correspond to those of topographic sheet. The line on which the profile is drawn is shown on the map.

These terraces are therefore interpreted as follows: When the waters of Lake Albany had so far subsided as to bring to the surface the deposits which now form the lower, or brick-clay, terrace of the Hudson valley, the Iroquois-Mohawk waters still discharged into the lake through the northern (Anthony kill) channel. In the progress of the subsidence the river currents, shifting eastward, cut down the inner portion of the clay terrace at Mechanicville and, due to the deflection of the Iroquois-Mohawk currents, southward through confluence with the southward-flowing lake currents, the area of reduced clay surface developed southeasterly. This process of erosion was brought to an end by a renewed and more rapid subsidence of the lake waters, thus causing the eroded area to emerge as land surface and forming the present terrace.

This terrace and the corresponding one on the opposite side of the valley are therefore features due to the destructive (degrading) work of river currents in contrast with the clay terraces which were built up through the deposition of sediments in Lake Albany.

In both cases, however, the marginal slope, determining the front of the terrace, is due to downcutting by currents shifted from a broader to a narrower range of erosion consequent upon the subsidence of the Lake Albany waters.

The downcutting which attended the renewed subsidence of the lake waters is definitely recorded in the steep slopes which bound the erosion terraces at their inner margins. As shown by the contour lines of the sheet the slope, or bluff, of the west terrace (facing the flattened area on which Mechanicville is built) is 60 feet in height and the bluff of the east terrace (extending northwesterly from Reynolds) is 80 feet. The trend of the lines of these bluffs is quite evidently such as would be caused by currents issuing from the Anthony kill channel. And these currents must have been of considerable power, seeing that their force was not spent in their diagonal course across the lake waters. It is therefore inferred that the Iroquois-Mohawk was still discharging into Lake Albany at Mechanicville when the waters of the lake had subsided to the level of the eroded area at the foot of the bluff west of Mechanicville. The eroded area just referred to has the physiographic form of a terrace normal to the river at the present level of its channel. The corresponding terrace on the east side of the river is the level tract extending toward the river from the foot of the bluff running northwesterly from Reynolds. These symmetrical terraces may be designated the lower erosion terraces in contradistinction to the upper erosion terraces described above.

EVIDENCE BEARING ON POSTGLACIAL HISTORY OF HUDSON-CHAMPLAIN VALLEY

These topographic features, due to erosion by the Iroquois-Mohawk currents, afford a datum for determining the time of subsidence of Lake Albany with reference to the location of the front of the ice sheet in its retreat from the Hudson and Champlain valleys. The outlet of the interior glacial lakes (Algonquin-Iroquois stage) continued through the Mohawk valley until such time as the receding ice front opened an outlet along the northward slope of the Adirondacks. It follows that the subsidence of Lake Albany had proceeded to the extent that its waters had lowered from the 360-foot level (that of the Hoosic delta) to the 100-foot level (that of the lower erosion terraces at Mechanicville) within the period of time the ice front was in process of retreat to the northern end of the Champlain region. For during the continuance

of the Iroquois-Mohawk outlet its currents lowered their bed in the Lake Albany deposits pari passu with the subsidence of the lake waters from the surface of the deposits to the level of 100 feet.

There is no evidence that the waters of the Hudson valley, after their subsidence to the level indicated by the eroded area at Mechanicville, rose again to a higher level. The present major topographic features of the valley (the terraces and their slopes) have certainly not been modified by overflowing waters since their origin. If therefore a water connection existed between the Champlain arm of the sea and the ocean at New York, this strait had a breadth at Mechanicville not greater than approximately the space between the 100-foot contour lines on the opposite sides of the valley; that is a breadth not greater than that of the present valley bottom.

These deductions, drawn from the facts of topography, are opposed to the conception of a body of marine waters filling the Hudson valley to a height indicated by the river deltas and continuous with marine waters in the Champlain depression.

If we suppose that the Hudson valley waters in which the sands and clays were deposited were estuarine, opening into the sea at New York, then that portion of the estuary included in the area of the Cohoes quadrangle had become changed to a fresh-water river while yet the St Lawrence basin was filled with ice. We are thus led to conclude that at no time was there a continuous body of marine waters connecting the St Lawrence arm of the sea with the ocean at New York.

Clays, sands and gravels on the floor of the Hudson valley. The materials of the floor of the Hudson valley are varied in character and over considerable extents of the surface are not readily resolvable into areas of distribution according to their composition and origin. This complexity is due to the varied factors that have determined deposition of materials and their subsequent degradation during the successive stages of Pleistocene history.

The strong currents which through downcutting brought into relief the clay bluffs bordering the valley floor did not sweep away all the deposits laid down on the middle portion of the basin of Lake Albany. In places, therefore, the soil is made up largely of clays representing original lacustrine deposits. Where these clays thin out or where they have been largely removed by erosion, glacial till appears, often with boulders at the surface. Where the erosion has gone on to the extent that the till has been removed, areas of bare rocks, or rocks covered with postglacial residual soils, occur.

At the base of the clay bluffs and in places extending well out toward the middle line of the valley there are low heaps or sloping banks of mixed clays and sands that have been washed down or have slidden in loosened masses from the slope. At a number of places there are evidences that landslides of considerable proportions have occurred. Thus on the left bank of the river above Stillwater, near the Washington-Rensselaer county boundary lines, the broken slope and partially detached masses of the clayey materials are quite evidently the result of landslides. Also 2 miles north of Waterford there is a conspicuous sloping bank, marked by the curve of the Champlain canal, which is believed to represent a landslide. The conditions and factors determining the occurrence of landslides of the Hudson valley clays have been carefully studied by Newland.[1]

It is quite probable that a considerable proportion of the fine-grained materials of the soils of the valley floor have been derived as silts washed from the numerous ravines that open into the valley. There are, however, no well-formed alluvial fans fronting the mouths of the ravines. In explanation of this it is to be remembered that the development of the ravines began as soon as the terraces emerged from the Lake Albany waters and that the sediments washed from the ravines were for a long time spread out on the bed of the lake when its shore line corresponded with the present bluffs of the lower terrace.

There occur here and there on the valley floor deposits of gravels; that is, rounded pebbles and cobbles, usually mingled with coarse-grained sands. Some of these occurrences admit of ready explanation. For instance, on the eroded tract crossed by the road that runs southwesterly from Reynolds the gravels, forming much of the soil of the fields, have evidently been derived from the materials of the Hoosic delta. The currents which reduced this portion of the front of the delta mass left behind the coarser parts which were too heavy to be transported.

There are frequent occurrences of masses of gravel in which there is a stratified arrangement of the materials. Immediately north of Waterford, in the angle between the canal and the highway, there is a conspicuous gravel bank in which the following features of composition and structure were noted: (1) Layers of coarse gravel mixed with dark sand 3 to 15 feet thick and 10 to 15 feet

[1] Newland. Landslides in Unconsolidated Sediments. 12th Rep't of the Director of the State Mus., p. 79. 1916.

in length; these layers mostly dipping to south. (2) Layers of dark sand mixed with pebbles and worn fragments of shale rock 3 to 10 feet thick. (3) Thinner layers of stratified yellow sands a few inches to 3 or 4 feet thick.

A gravel pit and slope showing a thickness of about 40 feet occurs along the road that crosses the eroded area northwest of Waterford near where the small stream crosses the road. This is apparently an exposure of the same gravel mass described in the preceding paragraph. Also on the northern part of Peobles island, south of Waterford, sand and gravel are obtained from deposits which apparently fill depressions of the rock surface. The materials show a stratified arrangement and consist of water-worn fragments of rock, ranging from the size of pebbles to cobbles, with irregularly interstratified layers and lenses of coarse sand, mingled with worn fragments of local rock.

These bodies of gravel are interpreted as representing kames, or morainic accumulations formed at the ice front in the retreat of the ice lobe which occupied the general valley of the Hudson after the melting of the ice from the uplands. As lacustrine conditions supervened these ice deposits were covered over with the clay sediments but in the localities mentioned, as elsewhere on the floor of the Hudson, they have been stripped of the clays and more or less reduced by stream erosion.

An interesting occurrence of gravels is that found on Green island and on the east side of the river, south of Lansingburg. Here the surface materials are limited to a thin layer of coarse sand and fine gravel immediately overlying bedrock. The thickness of this deposit, as observed, is nowhere in excess of 3 or 4 feet and in places it thins out to a few inches. The deposit lies unconformably on the rock surface, filling and smoothing over depressions in the rock. These sands and fine gravels are interpreted as outwash deposits from the morainic accumulations to the north and referred to in the preceding paragraphs.

The Willow Glen gravel bank. At Willow Glen the north slope of the valley now followed by Anthony kill presents an exposure of a thick mass of sand and gravel. The materials are utilized for building purposes and a spur of the railroad extends to the bank. The general composition and structural features are similar to those of the sand and gravel bank at North Albany. In general, the entire mass shows irregular stratification: layers of coarse gravels intermixed with coarse sands are clearly marked off

from layers of less coarse composition. Some of the layers are of dark color, due mainly to water-worn fragments of the local rock. At the base of the bed there are cobbles and boulders that have been separated from the sands in the work of excavation.

It is believed that these deposits are morainic in character and were laid down under conditions of standing water. They evidently occupy a preglacial depression and the retreating ice front may have halted or entered upon a phase of slow recession at this place. At the same time waters gathered in the depression and the materials derived from the melting ice were partially sorted as they were laid down.

This formation of sands and gravels, and others of similar composition and structure as they occur in the Hudson valley where lacustrine conditions immediately supervened upon the withdrawal of the ice sheet, may be designated as *subaqueous recessional moraines.*

Residual clays of postglacial age. The Mohawk waters which coursed through the Anthony kill channel swept from their path the Lake Albany deposits and laid bare the underlying rock. Much of this rock surface thus exposed to weathering is now covered with residual clay soils. In general, the floor of the valley from Willow Glen eastward to the river (except where bare rock is now exposed) is mantled with a thin layer of rock detritus soils of postglacial age. They are well shown in cuttings made in grading the macadamized road, and the transition from the fine-grained surface soil to the slightly altered rock below is readily noticeable. The depth of the soil, as observed, varies from a few inches to several feet. The park area of the city of Mechanicville is composed of this residual clay soil with some additions of materials from the lacustrine clays and sands that have been washed down from the slope bounding the erosion terrace.

When the Mohawk river became established in its present course (the Aqueduct-Cohoes channel) its flooded waters likewise swept away a broad path through the Lake Albany deposits. In this way was formed the broad depression extending southeastward from Crescent to the islands at the mouth of the Mohawk. The greater portion of the floor of this depression lies east of the present course of the river and is marked by striking irregularities of surface. The larger features are clearly due to the effects of weathering and stream erosion, mainly in preglacial times, of steeply tilted rocks composed of unequally resistant strata. The topography of this

area is therefore essentially preglacial and represents, in fact, a portion of the ancient rock valley of the Hudson stripped of its Pleistocene covering and somewhat modified by postglacial erosion and weathering.

The same area shows in its minor surface features the action of strong currents laden with fragments of hard rock as cutting tools. There are numerous depressions marking ancient potholes, now partially or wholly filled with the residual clays. Some of these are exposed where the clay is thin or has been removed; for example, on the left bank of the river near the falls.[1]

The surface materials of this area consist mainly of residual clays derived from the underlying shale (or slate) rocks. The section of the state barge canal which extends from Waterford to the Mohawk, at a point about 1 mile above Cohoes falls, crosses this area and is everywhere cut in bedrock. The layer of residual soil overlying rock is thus clearly exposed. Along the gorge of the Mohawk the weathered rock surface, forming a dark-colored clay soil, is also well shown. The thickness of the clay mantle is nowhere great, varying from a few inches to perhaps 5 or 6 feet. These clays have certainly originated as the products of rock-weathering since the end of the epoch of flooded Mohawk waters.

While the covering of this area consists predominantly of residual clays, there occur in places materials of the glacial till which escaped removal by flood erosion. These are scattered boulders and cobbles; also, in places, especially in the eastern portion of the area, some of the less coarse materials of the till still persist in the covering of the bedrock.

Areas of residual clays also occur on the floor of the Hudson valley. The largest of these forms a broad tract lying west of the curve of the river between Bemis Heights and Stillwater and extending in narrower development southward to near Mechanicville. This area includes many patches of outcropping or thinly covered rock, the distribution of which corresponds in general with the highest parts of the surface. In that portion of the area which lies east of the abandoned canal (which follows a line of drainage depression) the parts of highest elevation are shown by the looped contours marking the 100-feet level. But west of the road that runs northerly from Stillwater there is an elongated hill of rock with thin covering of detritus which is 160 feet in elevation. There

[1] For a full description of these potholes with measurements, see paper by G. K. Gilbert (Deposition of the Mastodon at Cohoes), N. Y. State Cabinet Nat. Hist., 21st Annual Report, 1871. p. 129–48.

is a depression of surface between this hill and the clay bluff which bounds the lower lacustrine terrace.

The interpretation placed upon these features is as follows: In the course of the lowering of the Lake Albany waters to the level marked by the base of the bluff fronting the lower terrace, the character of this body of waters had gradually become changed from lacustrine to fluviatile. Strong currents from the north flowed in the channel formed by the shrunken bed of the lake. At Bemis Heights these currents sweep southwestward along the clay bluff; subsequently the line of strongest currents shifted easterly, denuding the broad tract now covered with residual soils, and finally occupying the present channel of the Hudson.

In a number of places farther to the south there is like evidence of the erosive work of strong currents which flowed over the floor of the Hudson valley. The rock surfaces thus laid bare are now covered mainly by residual clays. The attempt has been made to map these areas, but in some places there are no clear delimitations and the boundaries as shown on the map are to be taken as approximate.

Areas of bared rocks. The areas of exposed rock surface on the floor of the Hudson valley and the two tributary valleys from the west are not sharply separable from the areas of residual clays described above. Both were originally swept bare by the same flood currents and it is probable that, excepting the rock islands of the Hudson river and other small exposures adjacent to the present streams, much of the area now bare was formerly covered with residual clays. The larger towns of the valley, Cohoes, Lansingburg, Waterford and Mechanicville, are built wholly or in part on rock and it is evident that human agencies have played a part in denuding these areas.

Postglacial gorges. The Mohawk river from near Crescent to its mouth has its bed on rock and in the last 3 miles of its course occupies a rock gorge marked by the well-known falls at Cohoes. A dam has been built across the upper portion of the gorge, in order to supply power for the industries of Cohoes. The level of the water in the dam is 156 feet. From the dam to the falls the river has the character of a rapids descending 20 feet in the distance of three-fourths of a mile. It then falls 70 feet over a precipice of rock. The water does not descend abruptly as a vertical sheet but flows over the steeply inclined rock declivity. The slope of this declivity corresponds in general to the dip of the rocks but

in the middle portion of the falls the rocks have been worn and broken so that the angle of fall is less than that of the dip and in places the falling water has the character of a cascade. At about one-third of the width of the river from the left bank there is a projecting mass of smoothed rock over which little water passes. At the inner side of this mass the volume of falling water is greater than elsewhere and at the base there is a deep pool of water occupying a depression worn into the rocks.

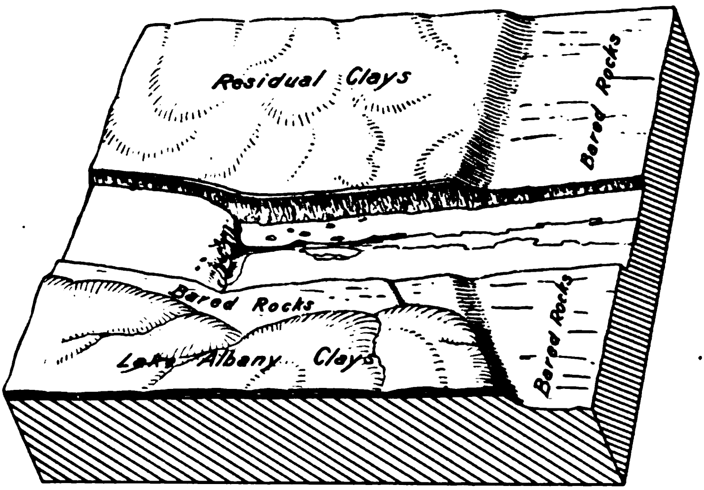

Fig. 7 Block diagram of the Cohoes region of the lower Mohawk. The development of the topographic features here shown is explained in the text.

Below the falls the river flows on a bed of jagged rock but with slower currents, descending in the course of a mile from the level of 60 feet at the foot of the falls to 51 feet at the head of the lower rapids where the river divides into three streams forming the islands on the floor of the Hudson valley. In the summer when the river is low most of the water below the falls is confined to a deep-water channel which extends from the deep-water pool at the falls.

In interpreting these features it is to be remembered that in this portion of its course the Mohawk flows across the ancient rock valley of the Hudson. The outer boundary of this rock valley is clearly indicated by the ridge (although now mostly covered) extending north and south from Crescent station. The postglacial Mohawk river broke through this boundary at Crescent. Then bending southward, its course partly determined by the strike of

the rock beds and partly by the slope of the old valley floor, the river eroded its present channel. Where it passed over the rim of the narrower inner portion, or gorge (see page 7), of the ancient rock valley, rapids were formed and, owing to the steep dip of the rocks, the rapids developed into a waterfall. This was the origin of the Cohoes falls.

The height of the rock wall of the gorge below the falls as seen on the east side is 120 feet. About three-eighths of a mile below the falls this wall falls away to a height of 40 feet. The contours of the upper portion of the wall, representing 80 feet, here become continuous with the slope extending northeasterly and bounding the present valley floor of the Hudson. This slope (crossed by the road a short distance back from the summit of the gorge) is composed of rock covered with residual clays. The continuation of this escarpment is seen on the opposite side of the gorge though much reduced in height and angle of slope for some distance back from the river. This is due to the flooded Mohawk waters of late glacial times, which laid bare the rocks on which the lower (northern) portion of the city of Cohoes is built. The trend of the currents southward due to their confluence with the Hudson waters, caused a greater reduction of the scarp immediately south of the gorge. But farther to the south, west of the railway tracks, where the surface of the rock is exposed in a ravine, the scarp shows at its full height.

It is quite evident that this slope of rock is the rim of the inner portion of the ancient rock valley and that the place where the height of the wall of the gorge below the falls abruptly lessens marks the original location of the falls of the river. The present Cohoes falls is located approximately 2000 feet back from this landmark, showing that a recession of the falls has taken place to that extent in postglacial times and subsequent to the withdrawal of the Lake Albany waters.

This small amount of recession compared with other postglacial falls (Niagara Falls has receded 7 miles in postglacial times) is explained, at least as to the main factors concerned, by the materials and structure of the rocks through which the gorge has been cut. The rock consists of indurated shales (slates) and sandstones, dipping steeply in a general direction to the east. The amount and direction of dip varies locally, due to contortions of the strata resulting from compression. In general, the sandstone layers predominate in the rock and layers of a thickness of from

several inches to a foot or more occur interbedded with the thinner layers.

The direction of flow is with the dip so that in general the wear of the rocks at the front of the precipice is on the faces of their bedding planes. Because of this the process of wear goes on slowly. But at the summit of the falls the water flows over the edges of the rocks and the destructive process is more rapid. The erosive agents lodge in the depressions resulting from unequal wear of alternating soft and hard strata and deepen them into potholes. There are very many of these in the bed of the river immediately above the falls. Due to the more rapid wear of the strata on their upper ends than on their faces, the angle of slope of the falls is greater than that of the dip of the strata.

At the base of the falls where the impetus of the falling water is greatest somewhat rapid wear takes place, forming pools, and the eddies in these pools, through undermining, may contribute somewhat to the recession of the falls.

The Hoosic gorge. A postglacial gorge of interesting physiographic and scenic features is that of the Hoosic river west of Schaghticoke. The river has here sunk its bed through the mass of delta deposits and into the underlying bedrock. Where the stream enters the gorge at Schaghticoke its course turns abruptly northward, evidently in conformity to the strike of the rocks. After emerging from the first gorge the river turns westward and its slopes consist of the delta materials. It then enters the second rock gorge and its further course describes the shape of the letter U, the direction of the arms of the U corresponding to the dip of the strata. There is a fall of 120 feet from the head of the upper gorge to the foot of the lower rock gorge, furnishing abundant power. This has long been utilized for manufacturing industries and, in recent years, for the generating of electric energy.

East of Schaghticoke the general valley of the Hoosic has the appearance of a preglacial valley although the shallow rock gorge at Valley Falls may mark a diversion of the river from its old bed. The course of the preglacial Hoosic from near Schaghticoke to the Hudson is unknown.

In that portion of the course of Tomhannock creek which crosses the delta formation, the stream has in places sunk its bed into the underlying rock forming gorges and cascades. One of these occurs a short distance northwest of Schaghticoke hill and another of picturesque scenic features about one and one-half miles farther on.

Plate 2

Falls of the Mohawk at Cohoes. The amount of rock erosion both above and below the falls on the left bank of the river is shown in the picture.

The gorge of the Hoosic river below Schaghticoke. The building in the middle background is the power house.

RECENT DEPOSITS

The deposits representing the recent period of geological history, or epoch that has elapsed since the final subsidence and disappearance of glacial waters, are (1) wind-blown sands, (2) stream alluvium and (3) vegetable debris or peaty accumulations in swamps.

Wind-blown sands. In the western and northwestern parts of the quadrangle there are extensive areas of country thickly mantled with loose sands. These sand fields are the eastern portions of a broad belt of sands that extends southwest from the region of Saratoga lake to the Mohawk river. To a large extent the sand is heaped in dunes, although, along the eastern margins of the tracts, there are stretches of nearly level country where the sand has been distributed somewhat evenly over the underlying till or lacustrine deposits. Many of the dunes are of live sand and show evidence of constantly changing size and position. They exhibit no general uniformity of shape but in individual cases it may be observed that their present growth is toward the form of a ridge with axis corresponding to the direction of the prevailing strong winds.

For the most part these sand tracts, especially the one extending southward from Saratoga lake, are uncultivated. Only the marginal portions of the areas where the depth of sand is not great are of any important agricultural value. The native vegetation consists of coarse grasses and of trees — pines, white birches and occasional oaks and maples. These trees are of second growth and are mostly undersized and often of stunted character.

The source of these blown sands is undoubtedly from deposits originally made in Lake Albany. To the westward from the sand fields south of Saratoga lake there is a nearly level plain (the Malta plain, Schenectady sheet) which bears evidence of having undergone denudation. The inference seems warranted that much of the sand of this field has been transported by the winds from the area of this plain to its present location. There is a similar relation between the sand region north of Crescent and a leveled tract to the west on the area of the Schenectady quadrangle. It is, of course, also to be considered that the prevailing strong winds of this general region are west or northwest.

There are two areas of wind-blown sands with well-developed dunes on the surface of the Hoosic delta deposits. Both of them lie near the eastern border of the delta region and are evidently composed of fine sands that have been sorted from the delta

materials by winds blowing from the west. Their locations are shown on the map. In other portions of the surface of the delta there are occasional dunes, but in general the materials of the delta are too coarse to be lifted by the winds.

Alluvium. The Hudson river is bordered by broad valley flats in its course from the northern edge of the sheet as far as Stillwater. The surface materials of these flats are the fine sediments or silts that have been deposited at times of high water when the river overflowed its banks. From Stillwater south to the head of tide water at Troy the work of the river in the recent epoch has been rather to lower its bed by erosion than to build up a flood plain. Some narrow areas of alluvial lands occur along the banks and in the curve of the river north of Lansingburg there are two islands of alluvial origin.

Along the Hoosic river the flats east and south of Schaghticoke constitute an interesting physiographical feature. It is evident that at a former time the river described a meander both on its right and its left bank. A factor in this shifting of its course was the rock barrier west of Schaghticoke which in times of flood held back the waters, causing the river to overflow its banks and diverting its currents against the valley slope. As this barrier was gradually reduced through erosion, forming the present gorge, the river straightened its course. The meanders were cut off from the main channel leaving, however, as a remnant, the present linked channels on the north flat.

An extensive alluvial flat, representing a recent meander of the river, occurs along the Hoosic in its lower course. As observed on the left bank of the river, the soil of this area is an alluvium with admixture of mold; it is of a high degree of fertility and is cultivated for market gardening products.

Swamps. Areas of swampy or partially drained lands, representing glacial lakes or ponds which have been filled in by sediments and overrun by vegetation, have been indicated on the map as far as observed.

REVIEW AND SUMMARY

The following is a classification of stages of the pleistocene period and present period as recorded on the area of the Cohoes quadrangle:

	NAME OF STAGE	PROCESS	RECORD
Present Period	Recent	Stream and wind erosion and deposition	Alluvium, wind-blown sands, swamp muck
	Glacio-lacustrine		
	Substage *e*	Erosion by fluviatile waters	Erosion terraces and eroded bottom of present Hudson valley
Pleistocene Period	Substage *d*	Later subsidence of Lake Albany	Lower terrace
	Substage *c*	Earlier subsidence of Lake Albany	Upper terrace
	Substage *b*	Lacustrine waters occupy Hudson valley	Lake Albany deposits
	Substage *a*	Ice lobe occupies Hudson valley	Marginal moraines
	Wisconsin	Last general glaciation	Till
	Pre-Wisconsin	(Interglacial interval)	Eroded basin of Saratoga lake (?)

In a previous report[1] the writer has presented what seems conclusive evidence that the Hudson river in its course across the southeastern spur of the Adirondack mountains, from Corinth to west of Glens Falls, occupies a valley cut during an interglacial epoch, immediately preceding the last or Wisconsin period of glaciation. On the area of the Cohoes quadrangle, however, no certain evidence of an earlier period of glaciation has been found. But mention may be made of the possibility that the rock depression occupied by Saratoga lake is a part of the valley eroded by the interglacial Hudson in its course southward from the place of emergence from the Adirondack region onto the Hudson plain west of Glens Falls. It has been thought permissible, in the classification above given, to recognize, in a tentative way, this interpretation of the rock basin of Saratoga lake with which may be connected that of Round lake, 4 miles farther to the south. Woodworth has suggested as follows: "It seems probable that Round and Saratoga lakes are unfilled depressions marking the site of an old valley west of the present Hudson gorge."[2]

[1] Glacial Geology of the Saratoga Quadrangle. N. Y. State Mus. Bul. 183, p. 30–35.

[2] Woodworth. Op. cit. p. 76.

The effects of a general ice sheet moving in a north-south direction, whether representing only the last invasion of the ice or the last, together with previous invasions, are recorded on the area of the Cohoes quadrangle in the smoothed surfaces of rock hills and in glacial scratches. The drumlinized forms of many of the rock hills are conspicuous to the eye in the field and are also clearly indicated by the contour lines of the topographic sheet. The character of the rocks (indurated shales and sandstones) and their steeply inclined planes of stratification are unfavorable for registering the ice movements by glacial scratches and they were observed only in two localities, as follows: about 1½ miles northwest of Stillwater, on the surface of a projecting mass of rock in a field south of the highway (see map), 10° west of south; about 1½ miles south of Valley Falls on rock at roadside, 5° east of south.

The close of the latest period of general prevalence of ice, marked by the retreat of the ice sheet to the north, is recorded in the materials left from the melting ice and forming the till sheet, or ground moraine of the uplands portions of the quadrangle. The recession of the ice front appears to have been relatively steady and uninterrupted. This is inferred from the fact that there is no recessional moraine of any considerable continuity. In a few localities on the eastern uplands areas, groups of hills of definite morainic character occur, evidently marking temporary and local standings of the ice front.

In the gradual process of the melting of the ice sheet the uplands were bared before the thicker ice filling the broad valley of the Hudson had wasted. A broad and deep lobe of ice thus lingered in the valley, probably for a long time after the upland areas were ice-free. South of the southern limit of the valley ice, and constantly extending northward with the retreat of the ice lobe, as well as spreading laterally over depressed areas adjacent to the Hudson valley, gathered and for a long time stood at a permanent level the body of waters which formed Lake Albany.

Due to the more rapid melting of the ice in its lateral portions than in the thicker middle portion, the ice lobe narrowed gradually toward its southern end and thus were formed two embayments of the lake waters, lying on either side of the elongated wedge of ice. These embayments received sediments derived from the melting ice and especially from streams from the north which developed in the depressions between the lateral margins of the lobe of ice and the bared land slopes. The coarser sediments were deposited in the upper and narrower parts of the embayments while the finer

materials were carried farther and laid down in the quiet waters lateral to the dwindling end of the ice lobe. As a general result of this sorting of the sediments, the materials deposited on the floor of the upper and outer portion of the preglacial valley of the Hudson are coarser (sands and clays of the upper terrace) than those which form the filling of the inner portion of the valley (brick clays of the lower terrace). The latter were added to, however, at a later time, by depositions of fine sediments from the midcurrents of Lake Albany.

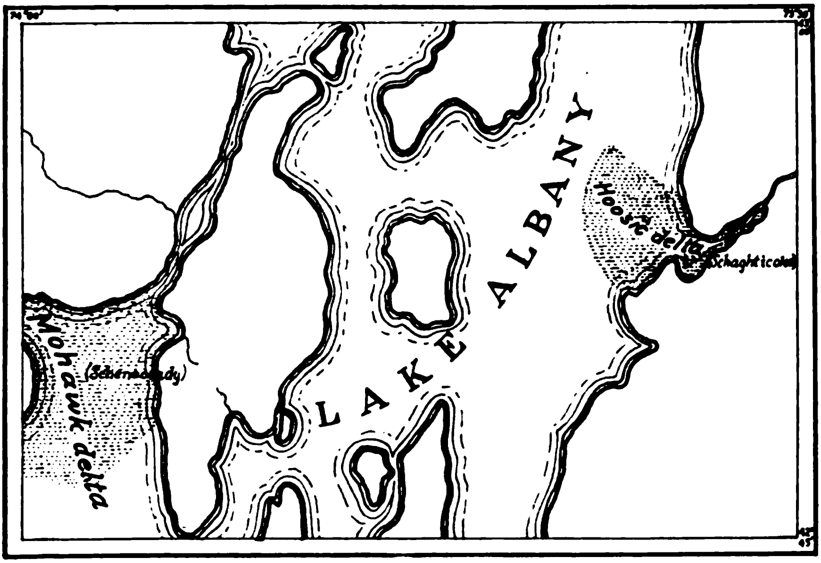

Fig. 8 Sketch map showing the distribution of land and water on the areas of the Schenectady and Cohoes quadrangles when Lake Albany was at the height of its development, its level corresponding to the present 360-foot contour

When the ice lobe had melted back beyond the northern limit of the quadrangle, all parts of the area the elevation of which is below approximately 360 feet on the northern portion of the present map and 320 feet in the southern were covered by the waters of Lake Albany. The lake waters rose beyond the height of the western marginal boundary of the preglacial rock valley of the Hudson and extended in two broad sheets westerly, communicating with the expanse of Lake Albany that overspread the eastern and southern portion of the area of the Schenectady quadrangle. The body of waters thus developed received the Hoosic river at its eastern border and the flooded Iroquois-Mohawk (then the outlet

of the great interior glacial lakes) at its western border. Each of these streams built extensive deltas into the lake. The magnitude of these deltas affords evidence of a prolonged period of stable conditions of the Lake Albany waters.

When at length the waters of Lake Albany began to subside the great deltas emerged as land surfaces. The emergence of the delta of the Mohawk influenced greatly the subsequent drainage history of the Mohawk-Hudson region. As the waters shallowed at the head of the delta near Schenectady, the checked Iroquois-Mohawk

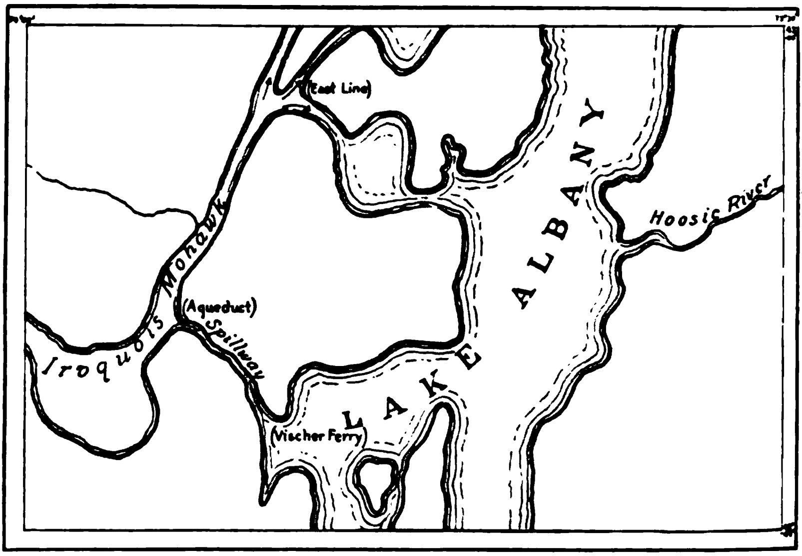

Fig. 9 Sketch map showing areal extent of Lake Albany and drainage courses on the areas of the Schenectady and Cohoes quadrangles at the time when the Lake Albany waters had subsided to the level represented by the present 320-foot contour

currents, impeded by their own deposits, were diverted northeastward through the Ballston channel, the latter opening into Lake Albany in the Saratoga-Round Lake region. At the same time, due to partial obstruction of the Ballston channel by sediments, a spillway across the barrier of rocks at Aqueduct was formed and a portion of the Mohawk waters discharged into Lake Albany at Vischer Ferry.

The northward course of the Mohawk waters continued for a long time. As the subsidence of Lake Albany progressed, bringing to the surface the lake bottom in the region of East Line, the currents eroded channels in the lacustrine deposits and eventually

the main course became established in the channel extending southeasterly to the Round Lake inlet of Lake Albany. At a later time, with a further subsidence of the lake waters, the Iroquois-Mohawk eroded out the broad and deep valley now followed by Anthony kill.

The Hoosic river, unlike the Mohawk, maintained its course across the emerged area of the delta, repeatedly shifting its channel from side to side and thus building a series of terraces.

The subsidence of the Lake Albany waters took place intermittently, as is shown by the distinctly terraced forms of the

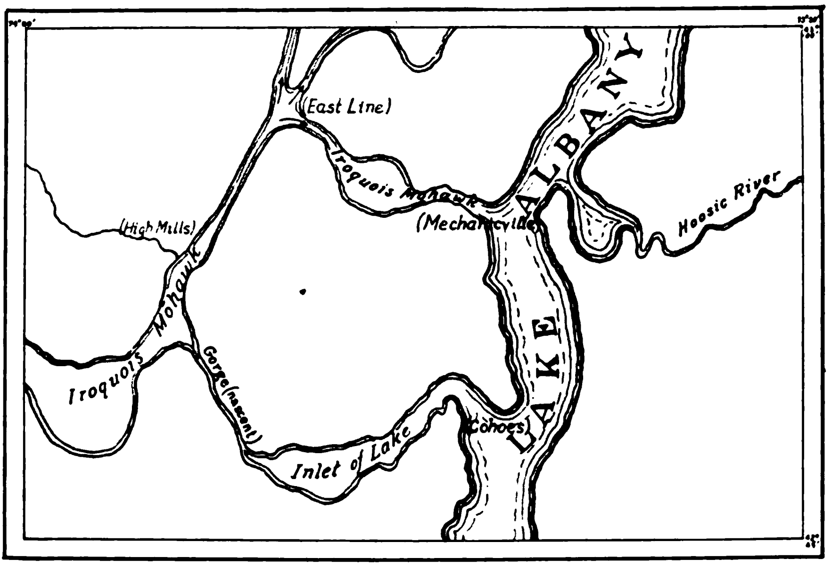

Fig. 10 Sketch map showing Lake Albany and drainage courses on the areas of the Schenectady and Cohoes quadrangles when the lake waters had subsided to the level represented by the present 240-foot contour

deposits. With the withdrawal of the waters to the level now represented by the 300-foot contour, or somewhat lower, the outer portions of the lake bottom in which the coarser sediments had been deposited emerged as land surface. Thus originated the present upper terrace of the Hudson valley.

At the next stage of marked subsidence, when the water had receded to the level represented by the 240-foot contour, or somewhat lower, the more even portion of the lake bottom which had been built up by deposition of the finer sediments, emerged as land surface, forming the plain of the lower or brick clay terrace.

The lake, then greatly narrowed, began to take on the character of a broad river and strong currents, coming both from the north and from the Iroquois-Mohawk which still discharged into the Hudson waters at Mechanicville, cut deeply into the sediments still filling the midportion of the general Hudson valley.

As a result of downcutting, symmetrical erosion terraces were developed at two levels on opposite sides of the valley at Mechanicville. The locations and configurations of these terraces show

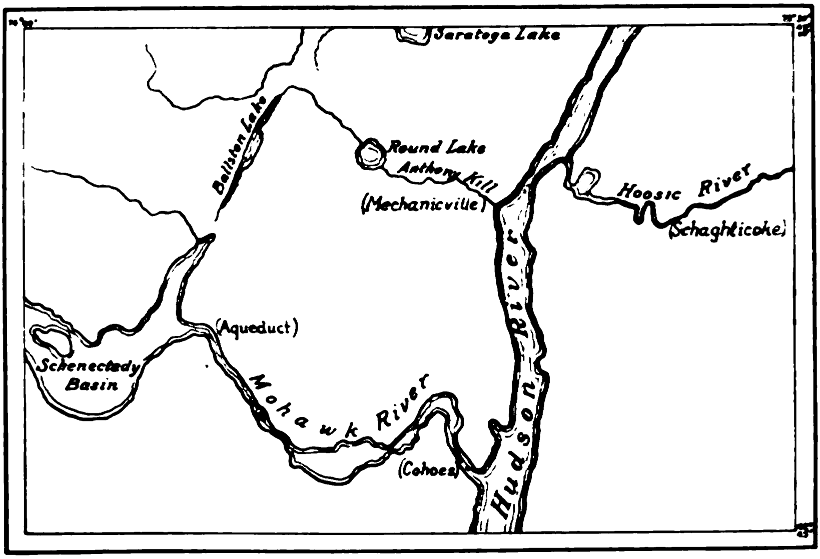

Fig. 11 Sketch map showing drainage of the areas of the Schenectady and Cohoes quadrangles and breadth of waters occupying valleys when Lake Albany had receded to the level represented by the present 100-foot contour line and had taken on the character of a broad river. The Mohawk river had lowered its gorge at Aqueduct to the 300-foot level.

conclusively that they were the work of the Iroquois-Mohawk currents and establish the fact that the postglacial body of waters of the Hudson valley became greatly diminished prior to the time of the opening of the channel northward to the Adirondack region as the outlet of the waters of the great interior lakes.

The spillway across the rock barrier at Aqueduct gradually deepened, through erosion, into a gorge of capacity sufficient to contain the volume of the Mohawk waters. The flooded currents cut a broad path through the lacustrine deposits southeast of Crescent, laying bare the rock floor of the preglacial Hudson valley. Where the river flowed over the rocky slope which marked the rim of the

ancient valley a falls developed which, through recession, formed the present falls and gorge of the Mohawk at Cohoes.

The stage of flooded waters in the Mohawk valley lasted until the general ice sheet had retreated to the north so far as to open a passage for the overflow waters of the great interior lakes north of the Adirondack region, thus diverting the outlet to the sea from the Mohawk valley.

Whether flooded waters continued for a still longer time in the Hudson valley depends upon whether the northern outlet of the great lakes, when first opened, connected with the sea through the St Lawrence basin as now or, for a time, found a course to the sea through the Champlain-Hudson valley. Assuming the latter case, there is no evidence that the flooded waters ever rose to a level higher than the foot of the clay bluffs bordering the present valley floor of the Hudson.

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